LOCOMOTIVES

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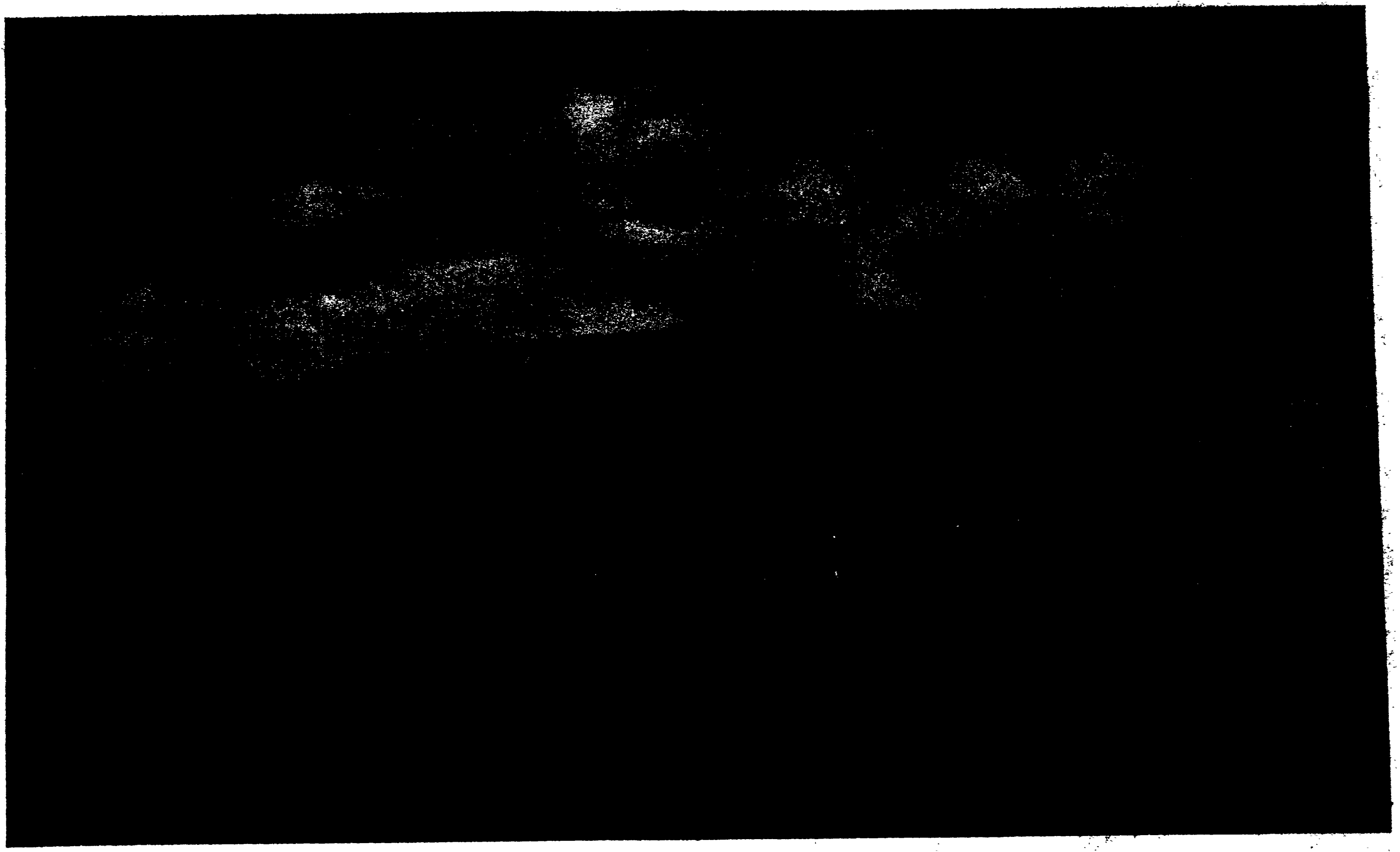
Frontispiece



London & North Eastern Railway, 2–8–2 Express Locomotive, No. 2001, "Cock o' the North."
Designed by Mr H. N. Gresley, C.B.E., Chief Mechanical Engineer. Built at the Doncaster Works.

LOCOMOTIVES

THEIR CONSTRUCTION, MAINTENANCE AND OPERATION

WITH NOTES ON ELECTRIC, INTERNAL COMBUSTION AND OTHER FORMS OF MOTIVE POWER

By

A. MORTON BELL, O.B.E.
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President Institution of Locomotive Engineers, 1935–36

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CHAPTER X

Repair Shops—Heavy Repairs—Lifting—Hot-boxes—Repair Cards—Setting-valves—Grinding, etc.

Repair Shops.

As an example of convenient repair accommodation, the plan is given of a depot recently installed on a Colonial railway, owning locomotives and rolling-stock of both normal and narrow-gauge dimensions. The general lay-out is shown in Fig. 1, and a detailed ground plan of the main shop in Fig. 2. Both 3 ft. 6 in. and 4 ft. $8\frac{1}{2}$ in. rolling-stock is handled in the same shop, consequently two four-rail mixed-gauge pits were constructed at track F (Fig. 3), giving room for stripping five locomotives or tenders of either gauge at one time. This and the tracks on either side are served by a 60-ton and a 10-ton overhead crane, which remove the boilers to the boiler shop in the rear and the frames to either side, according to gauge, over the appropriate pit for re-erection. The wheels, after having the boxes, etc., stripped, are then lifted on to the transfer track and rolled across to the machine shop bay, whence a

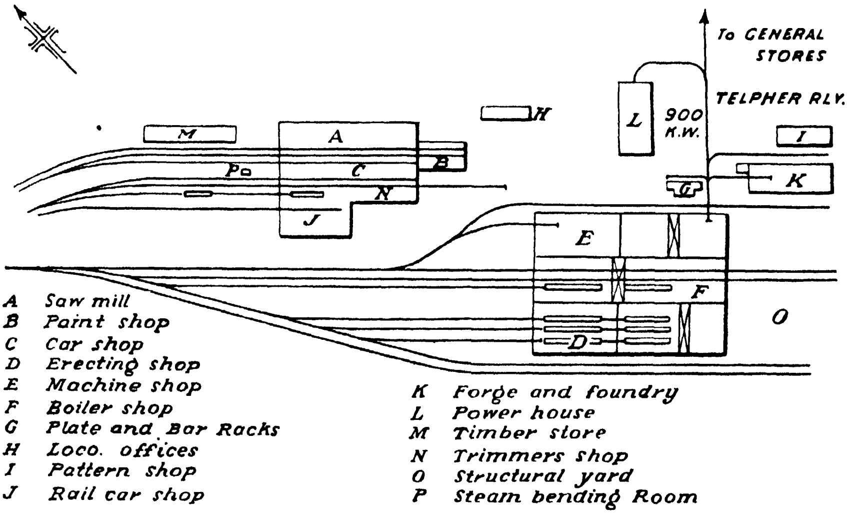

FIG. 1.—LAY-OUT OF NEW SHOPS.

10-ton overhead crane carries them to the wheel shop for retyring, turning, or whatever attention is necessary.

It will thus be seen that a smooth circulation of work is effected, the engines entering at track F and leaving by tracks E and G, with the minimum of shop interference. In practice, it has been found that this arrangement, with the exercise of a little thought on the part of the shop foreman, gives almost as good results as a side-by-side shop, but, of course, without the flexibility and expandability of the latter.

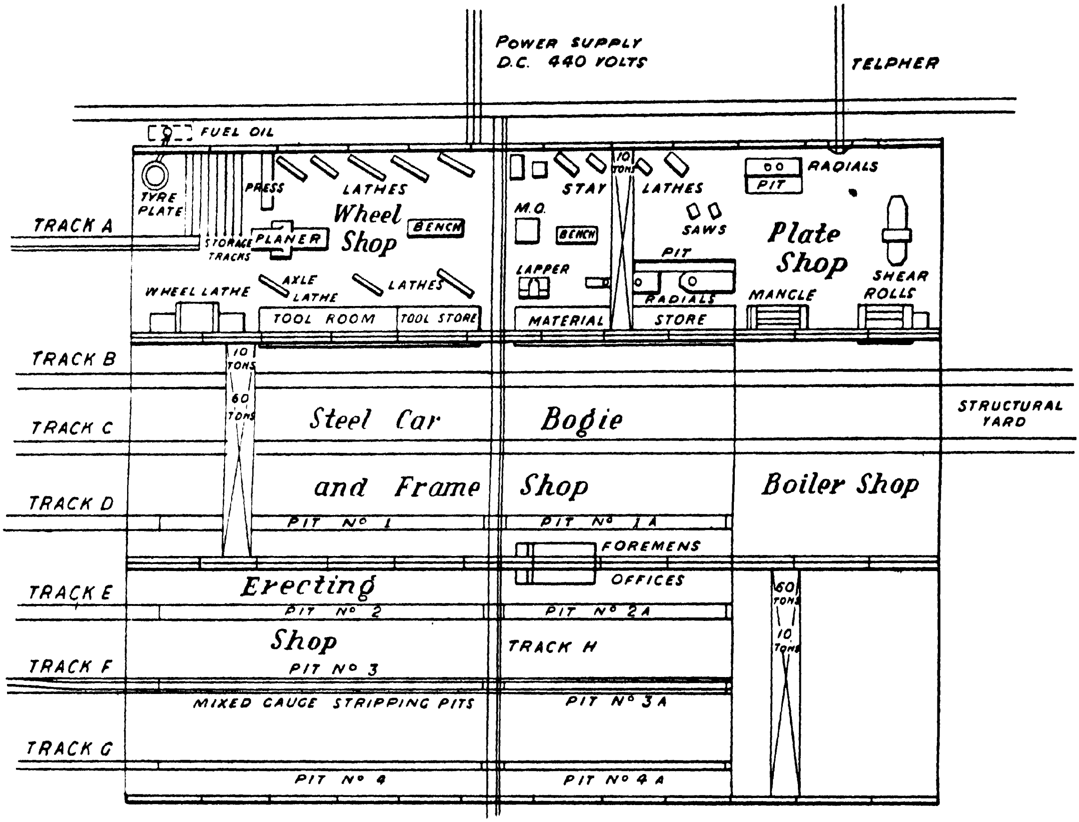

FIG. 2.—GROUND PLAN OF MAIN SHOP.

Owing to the mixed gauges the construction shown at Fig. 3 was adopted, using 60-lb. F.B. rails.

The rectangular recesses in the wall of the pit, house a three-pin power plug point, and a Westinghouse valve coupling for compressed air supplies, all hoses being fitted with similar couplings, thus eliminating all screw connections and accompanying losses. The connection or disconnection of a hose under these circumstances is effected almost instantaneously and maintenance costs reduced. By means of these boxes the shop floors are kept clear of trailing cables and hoses, with marked reduction in the amount of damage to these items. The electric conduits are buried in the walls, but the pneumatic mains run in channels on the face, where leaks can be detected and made good; ample mechanical protection is provided.

In addition to these pit-boxes, numerous electric and pneumatic power connections are provided along the walls and columns of the shop, and several three-pole iron-clad switch plugs, giving supplies of either 220- or 440-volt. current up to 50 amps. for various heavy portable machines through heavy armoured trailing cables. Earthing is effected here through the armour, a fourth pin on the plug making connection.

Among the machines driven from these plug switches are two arc welding sets and a portable radial drill used extensively for drilling out boiler stays, smoke-box rivets, etc., these appliances secure a large saving over the small portable tools commonly in use.

The power supply being D.C. 440 volts, it was necessary in the interest of economy of current and copper to keep circuits as short as possible, and as the supply entered the building at the middle of the N.E. wall, it was decided to supply the crane trolley wires from the middle and not the ends, as is customary. To do this, cables were run to the centre points and connected to the wires by means of the connections shown by Fig. 4.

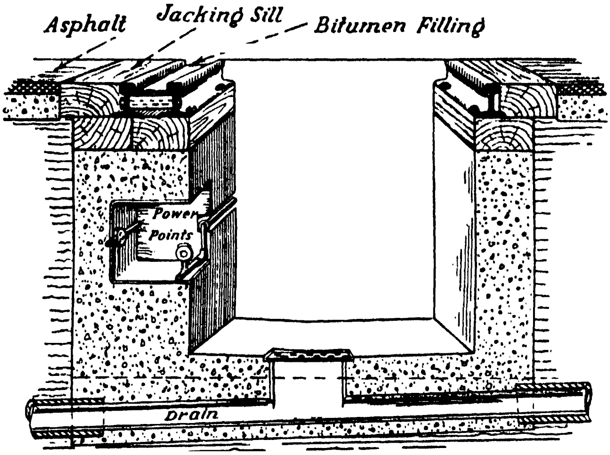

Fig. 3.—Section of Locomotive Pit.

Amongst the machine tools brought over from old shops those described replaced a number unsuitable for individual drive, and it was therefore necessary to provide two lines of shafting and countershafts. This was done, as shown in Fig. 5. The line shaft being below the countershafts offers many advantages, the load on the bearings is considerably lessened, belts and bearings get properly looked after, direct drives can be cheaply and simply arranged, and the stresses on the building become almost negligible.

Tubes are brought in cradles from the main shop and loaded into the rumble-drum; this drum is then lowered into a well and simultaneously into gear, the rumbling being done under water. By means of gearing the driving motor lifts the drum, and the tubes tumble out on to the rails and roll through a trap-door into the shop. Here they pass two saws, which cut off the damaged ends, and thence to a machine which tapers the end ready for re-ending. The same machine prepares the new end, which is pushed on, and the completed tube stacked ready for brazing. Brazing is performed on a machine fitted with a revolving rack and a hinged fire-bowl having a capacity of about sixty joints per hour.

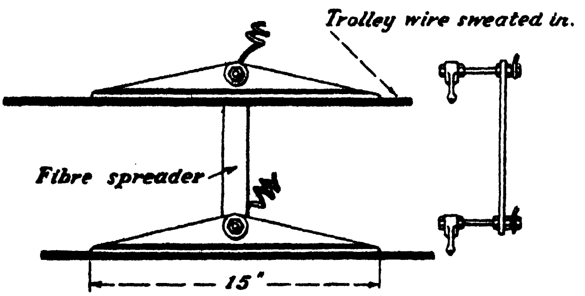

FIG. 4.—CRANE TROLLEY WIRE CONNECTIONS.

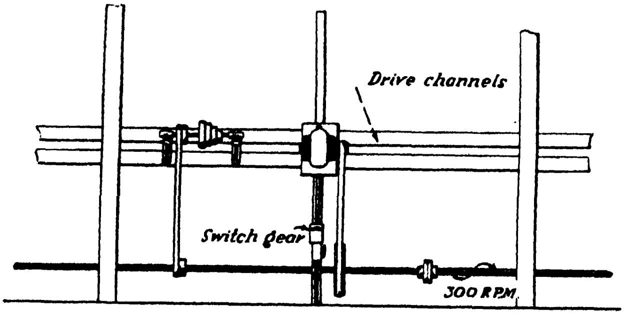

FIG. 5.—LINE SHAFT AND DRIVE CHANNELS.

All cables and pneumatic mains are carried in troughs constructed in the floor (Fig. 6), the courses of which are clearly shown on a plan in the shop and indicated by copper studs set in the bitumastic asphalt at each corner or junction. No fixed benches were allowed; each bench, 8 ft. long, is provided with two vises at opposite corners, and by means of lugs can be lifted and placed in any desired position by the crane; this results in the elimination of much waste time and effort.

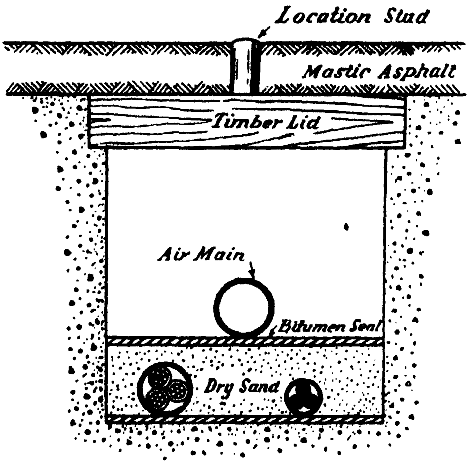

FIG. 6.—SECTION OF CONDUIT TROUGH.

Engine Repairs—Lifting.

Details of the engine, motion, etc., next call for attention, and where light repairs will be required for the axle-boxes, big-end brasses, etc. At all large running-sheds, lifting gear is provided, consisting of shear-legs made up of a framing set on four supports placed astride of a pair of rails, on which the engine to be lifted can be placed. These supports incline towards the top, or, in other words, "shear"; they may be of wood or steel, and must be built on a substantial foundation. Winding grips, or winches, are placed at one side of the base of the legs, operated by power in large depots, by hand in smaller. When hydraulic power is available a long cylinder is fixed vertically on top of the shear-legs and a plunger in this is coupled to the lifting chains, or ropes, thus securing a direct lift when power is admitted to the cylinder; time is much reduced by this arrangement.

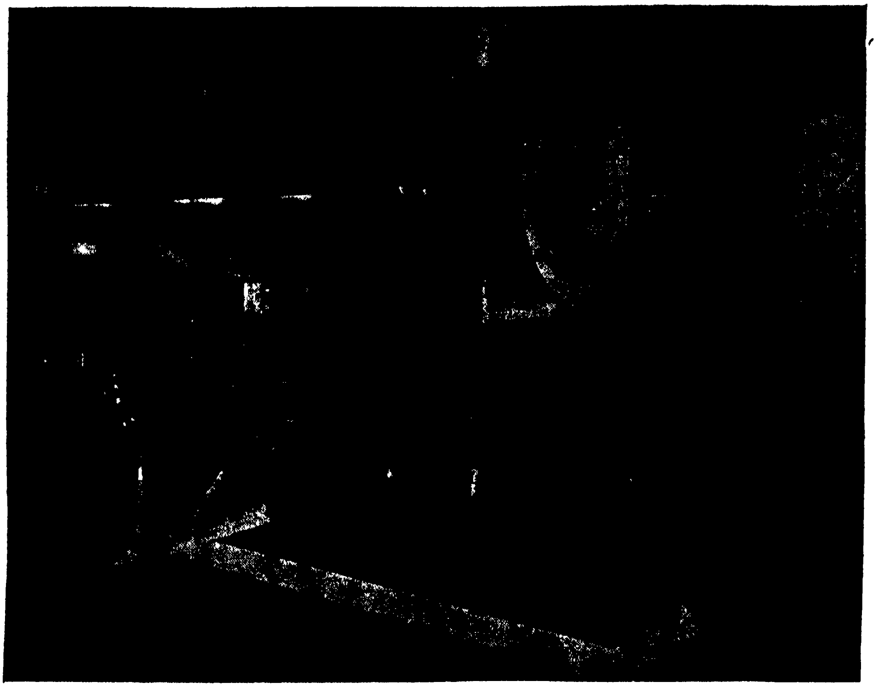

FIG. 7.—LOWERING BOGIE INTO DROP PIT, LONDON, MIDLAND & SCOTTISH RAILWAY.

The lifting hooks are placed under the buffer-beam at one end and packing-blocks built up on the rails are arranged under the buffer-beam at the other. These will act as a fulcrum when lift is applied. Stays and other necessary loose parts must be taken off before the engine is lifted. Modern express locomotives have to be raised a considerable distance to allow a pair of driving wheels to be run out, as only one end of the engine can be dealt with at one time with shear-legs, such as those mentioned.

In larger sheds where a number of engines have to be attended to, this work is now often carried out by drop-pits over which an engine is run and then the wheels dropped away from under it into the pit, whence they can be traversed to a convenient position for attention. Figs. 7, 8 and 9 illustrate the lowering away of a leading bogie axle and a pair of front drivers. A great advantage with this arrangement is that engines can be dealt with whilst in steam and in running order; the tender need not be uncoupled, or guard-irons or running gear disturbed.

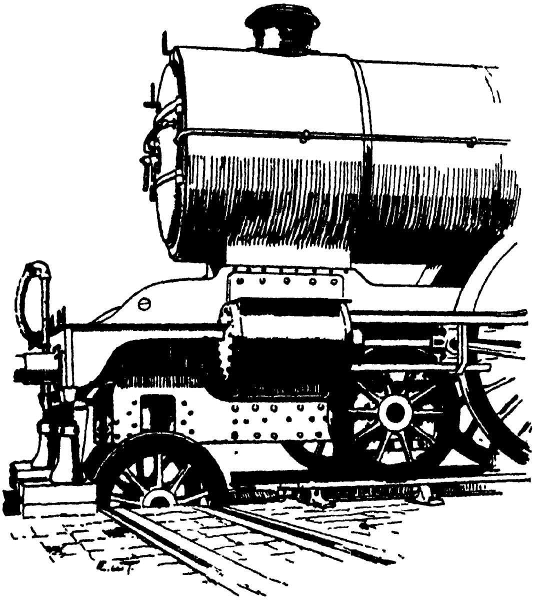

Fig. 8.—Lowering Leading Bogie Wheels.

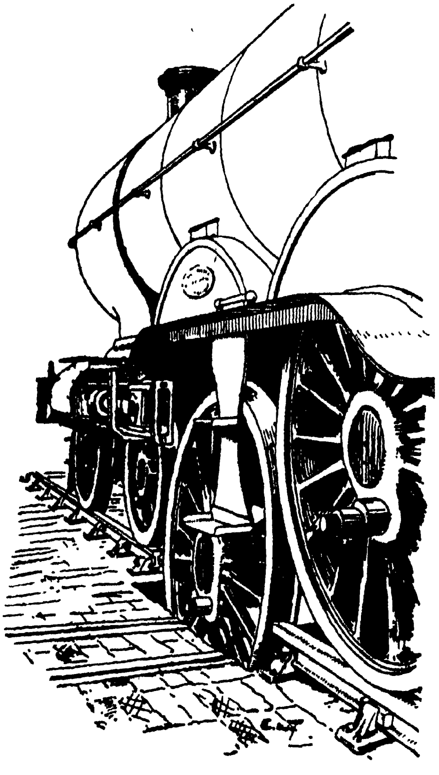

Fig. 9.—Lowering Leading Driving Wheels.

When dealing with a back axle-box, an engine can be placed with its wheels over the centre of the drop, its brakes being screwed tightly on to prevent any lateral movement; one pair of wheels is also wedged up. Screw-jacks are then placed under the buffer-beam to take the weight off the springs. Hydraulic power will cause the drop-table (Fig. 10) to rise to the flanges of the wheels and support them. When the pieces of rail are removed and the wheels lowered into the pit, a defective axle-box can be removed from its journal and readily attended to.

Economy in Repairs.

It should be the aim in every locomotive repair shop to keep engines in for the least possible time. One of the first helps to economical repairs is interchangeability of details, so that without having an undesirable amount of capital lying idle, sufficient spare parts can be kept in stock to meet demands.

A good basic principle in repairs, speaking of heavy overhaul, is to bring the engine back to " drawing " centres and sizes at each general repair. To accomplish this it is necessary to have all wearing surfaces easily renewable. This can be done on most existing engines by judicious alterations as they pass through the shops, and new engines can, of course, be designed in conformity with the general scheme. Under such a system it should be unnecessary to change or scrap cylinders owing to the barrel walls or valve faces being worn. It should rarely be necessary to change a crankpin or scrap a crosshead. Combination injectors often have to be scrapped owing to the clack-seats, cast integrally with the injectors, wearing thin with continual regrinding.

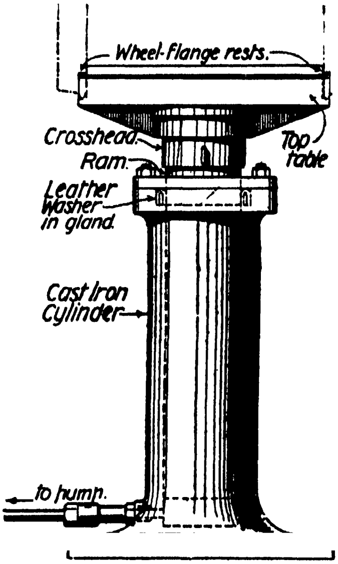

Fig. 10.—Drop-table.

Following this suggestion of ready replacement of details, cylinders might be bushed when new, and bushes changed as required. Valve faces could be provided with easily detachable false faces. Pistons could have the conical hole for piston-rod bushed with steel. Crossheads could have holes for gudgeon pin and piston-rod bushed. Cotter holes bushed. Slippers made small and detachable. Connecting and side-rod brasses or bearings could be advantageously made in the form of a mere cast-iron cage and completely lined with white metal. Valve buckles could be made adjustable. Slide bars could be fitted with detachable faces (Fig. 11).

Valve Motion Details.

All pinholes could be bushed, and links made in halves. Valve connecting rod could be made adjustable, and the reversing screw-nut could be bushed.

Framing, Wheels, etc.

Horn-blocks could be made with both faces removable, one parallel and one wedge (Fig. 12). Axle-boxes could be designed with brasses, side and face liners, and crankpins have hard steel bushes (Fig. 13). Spring hangers could have bushed holes and compensation beams have bushes and bearings for nib washers of steel, and loose (Fig. 14). Bogie: Swing links bushed. Centre-table bearing lined. Centre-pin holes bushed. Oil-cups: Trimming pipes screwed in—not solid with cup.

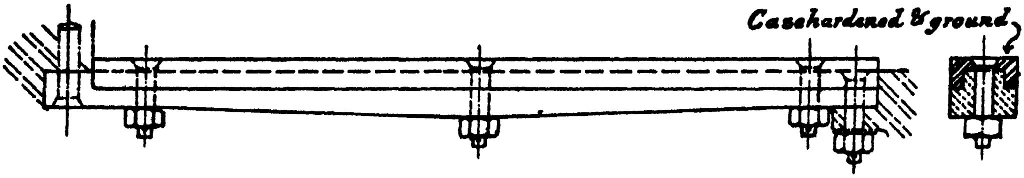

FIG. 11.—SLIDE-BAR WITH DETACHABLE FACE.

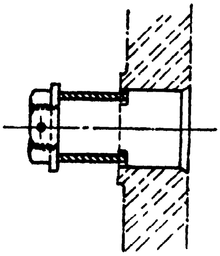

FIG. 13.—CRANKPIN STEEL BUSH.

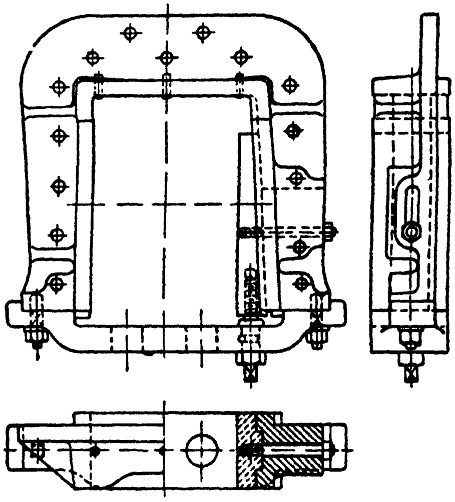

FIG. 12.—HORN-BLOCK.

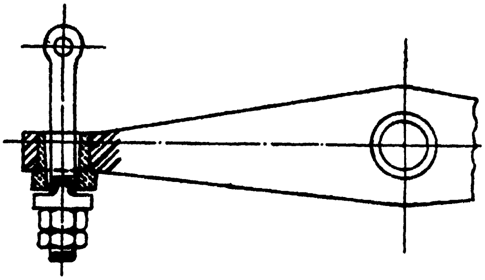

FIG. 14.—SPRING HANGER.

Boiler.

Where corrosion of the bottom of the barrel is prevalent it has been suggested that this could be prevented by sheeting with 1/32 in. copper sheet to above the water-line, but no results are on record of such procedure in practice. The use of compositions, adhesive paints, etc., applied both hot and cold, have been tried and in some cases have received very large adoption with acknowleged benefits. Tubes should be fitted with new external ferrules. These prevent the distortion so common to tube holes, and make it possible to withdraw tubes without damaging them. Grate: Experience with rocking-grates has demonstrated that their maintenance is not costly, and few spare parts are required; the pins on which the sections rock are the chief details needing attention. Injector clacks and other valves have been successfully used with faces of approved composition which, while always making a perfect joint in service, does not wear the valve seat, and only an occasional renewal of faces is necessary (Fig. 15). This material is also used as packing for gauge-glasses and rings for water, air and vacuum pump pistons.

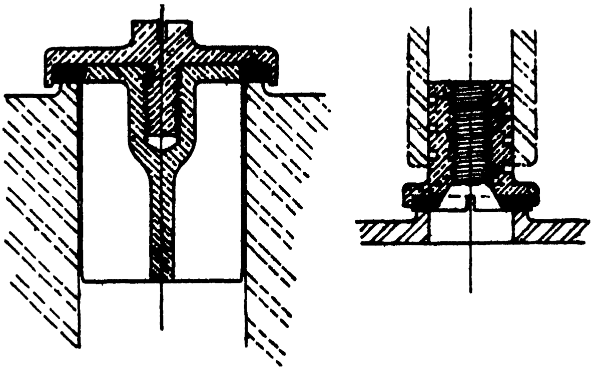

FIG. 15.—VALVE SEAT.

Organization of Staff.

The best organization of a repair shop consists in small groups of specialized gangs. The report of the running-department having been received on the particular engine for repairs, the chief boiler inspector will make his preliminary report—merely a general idea of the work to be done. If this will take more than a week it will probably be decided to replace the boiler with a repaired spare. To work this scheme successfully, each spare boiler will be complete with repaired fittings which are stamped with the number of the boiler—not of the engine—as where boilers are frequently changed they must bear a different serial or class number from the engine, *e.g.* Series 1-12 (engines), boilers 1001-012, so that no confusion of numbers is possible. A report sheet is then made out from the works manager's office after the style of Fig. 16, similar reports being made out for the boiler and tender; these reports are then sent down to the erecting shop foreman, who notes and allots the work to the various gangs, and to the boiler and tender shop foremen, who likewise make necessary arrangements.

It will be seen that the actual erecting shop gangs are cut down to a minimum and can consist of a charge-hand and an apprentice, who will spend their time in seeing that parts are completed and erected by specified dates. The actual stripping, repairing and re-erecting is done

SPECIMEN LOCOMOTIVE REPAIR SHEETS.

FORM A.L. Loco. Repairs.

A.B.C. RY. LOCOMOTIVE DEPT.

Engine No. 606, Class 460/3. requires the following repairs :	Boiler No. 6021.	Tender No. 10625.	Will arrive in Shops from Santa Cruz, date 1/2/36, and	
	For Inspector.	For Works Office.	For Foremen.	For Costing Office only.

Section.	*Details.*	*A. Work required.*	*B. Completion date.*	*C. Remarks.*	*Material costs*			*Labour costs*		
					£	*s.*	*d.*	£	*s.*	*d.*
Frames	Main frames.	Good—nil.								
	Cross stays.	"								
	Headstocks.	"								
	Hornblocks.	LL Loose.	9/2/36.	4 new 1⅛" bolts						
	Wedges and liners.	Renew.	4/2/36.	Renew.						
	Buffers.	Retemper springs.	9/2/36.	Retempered.						
	Dragbox.	Good—nil.								
	Drawgear.	Anneal.	6/2/36.	Annealed. D. Jones, Frame Foreman, 9/2/36.						
Set 460/12 Wheels and Axles.	Wheels.	Good.	Put in spare set 460/06. 6/2/36.	Set 460/06 put in.						
	Tyres.	Thin and hollow, renew								
	Axles.	Good.		Set 460/17 repaired and parked, 28/2/36.						
	Crankpins.	Worn, renew sleeves.	Renew tyres and crank pin sleeves and return to park 28/2/36.							
	Bogies.	Tyres thin, renew.		W. Wilson, Wheel Foreman, 28/2/36.						
Axleboxes.	Boxes.	Change liners.	Complete for set 460/12, 28/2/36.	Set for 460/06 fitted 6/2/36.						
	Keeps.	Renew 2								
	Brasses.	Metal up.		W. W., 6/2/36.						
Springs.	Springs.	Set up all springs.	5/2/36.	Springs set up, 8.						
	Rigging.	Renew pins and bushes.	5/2/36.	26 new pins, 26 new bushes. H. R., 9/2/36.						
Valve Motion. Set 460/4.	Eccentrics.	Take out and renew all pins and bushes and let links together.	28/2/36.	Repaired. 10 pins and 10 bushes renewed.						
	Rods.									
	Links.									
	Dies.									
	Valve rods.									
	Reversing shaft.	Fit spare set, 601/26.	7/2/36.	Set 601/26 fitted						
	Reversing gear.			D. Chorley, 7/2/36						
Cylinders.	Cylinders.	Change bushes.	6/2/36.	2 bushes fitted.						
	Covers.	Good.								
	Port faces.	Change false faces.	6/2/36.	2 false faces fitted.						
	Pistons.	Renew rings.	7/2/36.	6 rings renewed.						
	Rods	Good.								
	Valves.	Face up.	5/2/36.	Faced up.						
	Spindles.	Good.								
	Slidebars.	Renew liners.	5/2/36.	Renewed.						
	Crossheads	Renew slippers.	4/2/36.	Renewed.						
	Gudgeon pins.	Good.								
	Relief valves.	Grind in.	5/2/36.	Ground in.						
	Cylinder cocks.	Grind in.	5/2/36.	Ground in.						
	Ditto, gear.	Change pins.	5/2/36.	Changed 6 pins. L. Robinson, Cylinder Foreman, 7/2/36.						
Boiler complete	With lagging, mountings and ashpan.	Change boiler and repair for stock.	Fit boiler 6001. 6/2/36.	Boiler changed. H. R., 6/2/36.						
Cab and Platform	Cab.	Good.								
	Windows.	"								
	Platform.	"								
	Footsteps.	"								
	Sandboxes.	Clean out.	6/3/36.	Cleaned.						
	Ditto gear	Renew pins.		8 pins renewed. J. Smith, 9/2/36.						
Rods.	Main rods.	Change all bushes.	Fit set 601/23, 9/2/36.	Fitted 9/2/36.						
	Coupling rods.	" ,		J. C						
Valves.	Setting.	Re-set.	Set No. 3 setting, 10/2/36.	Set, 10/2/36. H.P.						
Steam Test.		To steam.	Steam, 10/2/36.	Steamed, 10/2/36. O. K.						
Brake Gear.*	Blocks.	Change.	Changed 6 blocks, 9/2/36.	Changed 6.						
	Hangers.	Rebush.		Renewed 12						
	Ejector.*	Good.								
	Connections.	Renew rubber hose.		Renewed 2 large, 1 small.						
	Cylinders.	Renew rolling rings.		Renewed rings. S. R., 10/2/36.						

by small specialized gangs. If an engine is to be completely painted it will be necessary to add another ten days for the paint shop.

The system of standardization outlined above greatly facilitates running-repairs. A badly cut crankpin could have its sleeve replaced by a new one in an hour. Side-rods, bushes, etc., could be stocked ready machined to standard sizes. Fire-bars, of which an enormous stock has to be carried in a large shed, should be cut down to a minimum.

FORM B. Interchange Sheet.

Engine 606. Class 460/3. Series 601–630.
Put in service 1/1/30.

Date in.	*Date out.*	*Boiler No.*	*Tender No.*	*Wheel Set No.*	*Motion Set No.*	*Rod Set No.*	*Remarks.*
5/3/33		6,006	10,606	640/6	601/6	610/6	
	20/3/33	6,021	10,625	460/12	601/4	601/10	First repair.
1/2/36		6,021	10,625	460/12	601/4	601/10	
	12/2/36	6,001	10,651	460/1	601/26	601/18	Superheated boiler.

Mileage: 1. 100,000.
2. 98,762.
3.

FIG. 17.

FORM C. Boiler Card.

BOILER 6021.
SERIES 6001–6460.

Built 22/34. Put into service 1/1/25. In Engine 621.
Class 460/3. Fire-box, Copper. Tube-plate, Steel.
Tubes, Steel. Interchangeable with Engines 101–160 (442/1), 301–600 (280/1), 601–630 (460/3) and 1001–1040 (460/2).

Date in.	*Date out.*	*Engine No.*	*Class.*	*Ref. to Repair Sheet.*	*Remarks.*
	1/1/30	621	460/3	—	New.
4/2/30		621	460/3	AB, 6021/3/33	
	8/3/33	451	280/1	—	
1/3/33		451	280/1	AB, 6021/3/27	
	12/4/36	1032	460/2	—	

Boiler complete with lagging and following mountings: 1 regulator, 1 No. 8 H.W. injector, 1 No. 12 ditto, 1 gauge mounting, 3 test cocks, 1 steam sand-valve, 1 blower valve, 1 steam fountain, 1 steam gauge, 1 vacuum gauge, 2 blow-down cocks, 1 steam heat valve, 1 steam heat gauge, 1 type " C " brake ejector, diaphragm plate.

FIG. 18.

The book-keeping for this class of repair organization should be by a system of loose cards, of which two examples are shown (see Figs. 17 and 18).

The complete list of these is:

AL	Locomotive repair sheet.
BL	Boiler repair sheet.
TL	Tender repair sheet.
B	Interchange sheet.
C	Boiler location card.
D	Tender location card.
E	Motion and rod location card.
F	Wheel location card.
G	Shop job card, and time card.
H	Locomotive costing and depreciation card.
I	Tyre and axle mileage.

Forms BL and TL are similar to AL, and forms D, E, and F are similar to card C. It will be seen that each engine, boiler, tender and set of wheels, rods and motion has a card of its own, the whole being cross-entered on card B. Card I, which is supplementary to card F, deals entirely with the mileage of tyres and axles, as apart from the engines.

Having outlined the possibilities that will accrue by efficient construction of details connected with easy maintenance and repair, with the approved procedure for securing attention, it is desirable to mention some of the more important items needing repair and care in shed, especially the lifting of engines.

Connecting Rod Big-ends.

Should a considerable " knock " become apparent in an engine when running, it should be the driver's business to make a thorough examination of the motion at the earliest possible opportunity. There are many places in which a knock will develop, and it is not always possible to locate it while the engine is running; but the following are the parts which may be examined with a view to discovering the trouble: all the slide-bars and their bolts, the crosshead cotters, small-end brasses and adjusting bolts, the big-end brasses, bolts and straps, and finally the axle-box wedge bolts, which sometimes slack back and occasion a heavy knock.

If the crankpins of an engine which has been in service some time are carefully calipered, it will be found that the journals are worn to an irregular shaped oval, which, unless rectified, will produce constant trouble. This unequal wear is due to the fact that these bearings were subject to varying pressures during their rotation; for example, a main line engine usually runs in forward gear, and the areas of the crank web journal that wear most rapidly are those whereon the maximum pull and thrust of the connecting rod take effect whilst passing the top and bottom centres respectively; this uneven wear cannot be taken up by the cotters.

An important factor in securing cool running is the quality of the white metal used in the brasses, and its freedom from dirt and grit when placed in the recesses. In fitting, it is advisable that the surfaces of these brasses should be finished with a smooth file rather than a scraper, as the few grooves left by the former tool hold the oil, thus giving the brass a good start when newly fitted.

The big-end is a detail which is subject to knock and other troubles, so that a few hints as to dealing with it will not be out of place. Before commencing operations, it is desirable to open the cylinder drain-cocks so as to free the cylinder of steam, which otherwise might, by its pressure on the piston, give the impression of a tight big-end brass. To tighten a loose big-end, a good practice is to get the crank first on the bottom centre. Then mark the adjusting cotter with some sharp-pointed tool—the corner of a chisel will do—immediately below the big-end strap, so that, as it is subsequently driven in to tighten the brasses, this mark shows the extent to which it is moved. Having got a good running fit in this position, move the engine so as to get the big-end on the front centre, and test it carefully to see whether it is free to move sideways on the journal before tightening up the set-screws. The reason for this double adjustment is that sometimes big-end journals are not perfectly cylindrical, and a test in one position only might not make due allowance for a tight fit elsewhere, with consequent trouble through heating.

The trimmings of big-ends have much to do with their liability to, or freedom from, heating. These trimmings should be changed from time to time, especially with sudden variations of weather, as the character of oil undergoes great modifications according to temperature. Thus, a tighter trimming is suitable for hot weather, but might cause much trouble in colder weather, when the oil does not flow so readily.

The length of the trimmings is also a factor of considerable importance. They should go down through the strap and well into the brasses, reaching to within $\frac{3}{4}$ in. of the journal. If the trimming is too short and the brasses are not a good fit in the strap, there is a risk that the oil will flow out between the strap and brasses, and not reach the journal at all. It should be remembered also that big-ends always run best if the brasses are fitted brass to brass, as in that case the lubricant is retained where it

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is wanted. Where brasses are left with a "draw" on them, the oil gets out and trouble often ensues.

While on the subject, it may be mentioned that defective lubrication in the cylinders will often cause a heated big-end when "coasting" down a long bank, with steam shut off; in such a case the piston drags heavily on the cylinder wall and causes an undue pressure on the big-end.

When, from whatever cause, a big-end has heated, it is well at the outset to slacken the cotter slightly to allow for the expansion of the hot journal. A slacker trimming should be put in to allow for a better supply of oil, and if this is properly done a thicker oil may be used, which will be found to act as a preventative of further trouble. Plenty of fairly thick oil is required in the first instance to free a big-end that has heated and seized, and it will be found distinctly helpful to get some oil into the journal from between the brasses and the webs.

Where an engine has to work over a road with a number of sharp curves, care should be taken to see that the big-end brasses have some side-play between the crank webs. In almost any case, brasses that have any considerable bearing on the radius of the crankpin are sure to give trouble sooner or later.

Refitting Big-end Brasses and Axle-brasses.

In running-sheds where there is no lathe or similar machinery, the work of refitting a big-end or axle-box brasses is greatly assisted by the use of a few cast-iron hollow mandrels made in different sizes to suit the variations of diameter of the journals in service. The mandrel is turned up on the outside only to suit the diameter of the journal, and is fitted with two sliding radius rings which are fastened on to the mandrel by two set-bolts, thus being adjustable to suit the length of brass dealt with. These mandrels are very useful in the case of engines fitted with cast-steel axle-boxes and bearings which can be removed when heated for re-metalling, as after the brass has been re-lined with anti-friction metal the bearing can easily be refitted and bedded down quickly by putting a little "marking" on the mandrel and trying it on the brass, this answering the same purpose as testing on its own journal.

In most running-sheds the time available for re-metalling and refitting a pair of big-end brasses is very limited, and the fitter who has the job in hand has to do the work as expeditiously as possible, so that the engine may take its proper place in service.

With the assistance of one of these mandrels (Fig. 19) after the big-end brasses have been re-metalled, the hard places are quickly removed from the bearing surface by the aid of a rasp and scraper before the metal gets quite cold, thus saving time by avoiding the journey to, and from, the vise. When the brasses have their proper bearing they can be placed together to see if they require reducing on the ends to take up slack. For this the mandrel can be placed between the brasses and a good idea formed as to how they will fit the journal. Finally, they should be taken under the engine and tried on a big-end journal, the liners adjusted to suit the cotters and coupled up to the connecting rod.

Hot Boxes.

An ailment which affects all locomotives at times is the " hot box," and a frequent cause for anxiety on the part of the running-shed foremen. The chief causes of trouble are insufficient lubrication, wrong brand of oil, badly made trimmings, and dust or sand working in between brass and journals; cases have been known, however, where boxes run hot owing to the incorrect alignment of the frame. On the road, little can be done beyond oiling freely and taking advantage of the next stopping-place to see that the horn-wedge is sufficiently slacked back to prevent seizure due to expansion.

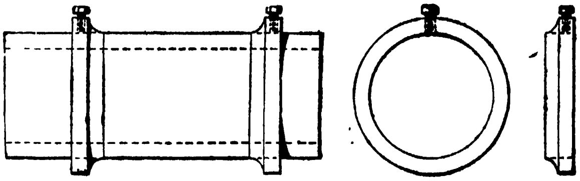

FIG. 19.—MANDREL.

Lifting.

In the following remarks, on lifting, it is proposed to deal firstly with driving, or coupled, boxes, and particularly with the separate brass type of box purposely adhering to British practice and refraining from dealing with other than the ordinary forms of spring gear.

Driving Boxes.

At the running-shed, the general procedure is to lift the engine clear of the wheels to which the faulty box is attached, or, if the shed be equipped with a hydraulic drop-table, to drop the wheels from under the engine. Occasionally, however, it may be inconvenient to remove the wheels, in which case the engine must be lifted enough to allow for removal of the brass alone. Assuming, then, that it is possible to remove the wheels, the coupling rods must first be detached, taking care to screw back the caps on the crankpins to prevent damage to the threads. Guard-irons or any other obstruction having been removed, the engine must be lifted so that the wheels concerned are just clear of the rails, taking the weight off the springs. If the hot box is a trailing coupled one on a bogie engine, involving the lifting of the back end, it is necessary to remove the bogie centre-pin nut and to insert two pieces of packing (not less than 4 in. thick) between the centre faces to allow free movement of the centre pin. Also, when lifting the front end of an engine with a trailing radial, small pieces of packing should be placed between the top of the box and edge of the frame. Should, however, the wheels be set on a drop-table, the latter may be used to lift the few inches necessary to overcome the resistance of the springs. Having done this, the centre pin connecting the axle-box to the spring, is knocked out (if the spring be of laminated type) with a long steel punch and quarter hammer. When the pin falls out, it is advisable to allow the punch to remain in the hole, the weight of the spring holding it there. The end pins are now removed and the spring dropped into the pit by withdrawing the punch. Coiled springs are removed simply by unscrewing the nuts and allowing them to fall off.

The engine can now be lowered, or the wheels dropped back for the removal of the horn-stays. It is as well at this point to disconnect all oil-pipes from the tops of the boxes, and if the tops be recessed to form an oil-well, to lift the lids. This done, the engine must again be lifted, to permit the removal of the "tee links" and pins, and all should then be ready for the wheels to be put clear of the engine.

If the axle-box keep is secured by pins, these are now knocked out. Stout pieces of timber should be placed across or at the bottom of the pit directly beneath the defective box, to prevent damage to the brass, etc. The box may now be swung round, keep uppermost, on the journal, when it will usually drop off by its own weight.

In the separate brass type of box, the removal of the brass is effected by inserting a stretcher bolt between the jaws of the box.

To remove the brass, in cases where it is inconvenient to set the wheels clear, however, the procedure may be based as follows:

Having taken down the springs, "tee links" (on both sides, as before), oil-pipes and keep, the engine should be lifted (or the wheels dropped), just far enough to prevent the boxes leaving the horns. The stretcher bolt can now be inserted at the lowest possible point between the jaws of the box. The box must now be lifted, so that the brass is well clear of the journal, taking care that the horn-wedge is slacked back to its fullest extent. The best way to lift the box is to jack it up with a light jack, packed off the floor or side of the pit. As soon as the brass is sufficiently clear, a small piece of wood should be placed between it and the journal, and the stretcher bolt expanded to its fullest extent. If the brass is not a tight fit it will drop on to the piece of wood and can then be lifted out; but if the opposite is the case, it must be forced down by means of a tommy bar and then, if necessary, bumped out with the aid of a piece of wood and a quarter hammer.

After the brass has been metalled, the radii at each end should be roughly formed with a rasp while it is still hot. It will then be ready for the reception of the mandrel of corresponding size to the journal. Marking is rubbed on the surface of the mandrel and this is best prepared by mixing a little thin oil with lampblack. In trying the mandrel in the brass, care should be taken in revolving the former to move that part of its circumference adjacent to the brass, thus preventing rocking and side play. The rest of the process involves judicious use of scraper and file, to produce an even surface of white metal.

If the journal has been "scored," the marks should be eliminated as far as possible with a smooth file and emery paper.

Before they are replaced, both brass and keep must be scrupulously cleaned, and the oil-holes cleared by pulling a trimming through them.

The replacement of brasses, boxes, springs, etc., follows the removal process in reverse order. A clean spring-pad should be placed in the keep and clean horsehair or similar elastic material in the oil-well on top of the box.

Bogie, Pony Truck and Radial Boxes.

In bogies, box and brass are sometimes in one, so that it is only necessary to detach the horn-stays and lift the engine to free the wheels and boxes. The wheels can, of course, be lowered out on a drop-table, provided that the weight of the engine supported by the bogie is taken by jacks or the shear-legs.

Pony trucks and radial boxes are similar in construction to bogie boxes, and the former are removed by taking the weight off and dropping the springs, followed by the usual procedure.

In removing the latter, the horn-stays must first be detached and the side-controlling springs uncoupled and put out of the way.

Both journals and bearing surfaces undergo the same treatment as in the case of driving boxes.

Re-metalling and Fitting Eccentric Strap Liners.

Modern locomotives are often provided with eccentric strap liners filled with anti-friction white metal, which as a rule work very satisfactorily; they are, however, liable at times to pick up grit and dirt, which causes them to run hot, with the consequence in extreme cases of fusing the metal in the liner. This is a class of mishap with which a running-shed is expected to deal; but when the appliances available are somewhat limited, special devices of a simple nature have to be utilized, one of which is described below.

As the liners are generally made of cast-iron, they have to be carefully handled in order to prevent distortion and to keep them a good fit in the strap; otherwise they will give further trouble on being put back in place. After being removed, they are placed over a clean coke fire and slightly heated, and are then thoroughly cleaned and tinned ready to take the white metal.

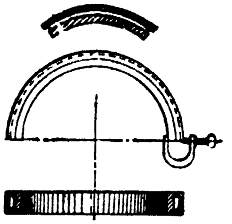

FIG. 20.

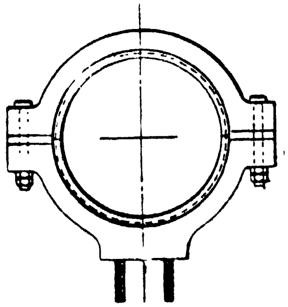

FIG. 21.

FIG. 22.

White Metalling Liners.

The accompanying illustration shows a common method of procedure. A piece of wrought iron is turned accurately to fit the inside curve of the liner, and is clamped to it in the manner shown in Fig. 20, in elevation and section. The white metal is then poured into the channel until it is completely filled.

The next process consists in fitting the two filled liners into the strap, as shown in Fig. 21, to be bored out; the oil-hole is drilled out prior to the strap being put into the lathe. A wire gauge is employed to get the exact diameter of the eccentric sheave, and two other gauges, shown fitted together in Fig. 22, are used to ensure getting the exact width externally and internally, thus ensuring a good job being made of the new metalling.

After being accurately bored, the liners are taken out and the oil-holes countersunk and eased at the ends, by means of a flat scraper, to assist in securing perfect lubrication all round the sheave.

The liners are again fitted in the strap, which is placed on the sheave and tested with a little marking so that the tight places may be reduced and a good crown bearing obtained. Care must be taken that the strap is not bolted up too tight, a play of 1/32 in. being usually provided with suitable brass linings placed between the two halves of the strap.

In coupling up the eccentric rod to the strap care must be taken that the strap has no spring sideways and bears equally on the sheave all round. The rod should be in perfect alignment from link to strap, and parallel to the centre-line of the engine; otherwise further trouble may be expected from the heating of the strap.

Setting Locomotive Piston Valves.

The necessity of accurate valve setting relative to the efficiency of a locomotive is a factor too obvious to require emphasizing, and on these grounds a description of the methods designed to give results, correct to a very fine degree, may not be without interest. For purposes of illustration, an example will be given of an engine fitted with piston valves—a type on which much closer setting is possible than in the case of engines fitted with flat valves. The reason of this is that, generally speaking, except in a case which will be referred to later, each valve head is independent of the other, and each can be adjusted to govern—within close limits—the admission of steam at its respective end of the cylinder.

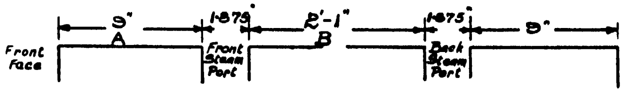

FIG 23

In the first place, then, the sketch (Fig. 23) shows how the measurements of the position of the steam ports relative to the front face of the cylinder are to be taken. The dimensions thus obtained form the basis of all valve-setting calculations, both when the engine is first erected, and at any later stage of its life, when returned to the shops for overhaul. In fact, right until the time when the valve liners come to be withdrawn. Records are made of these figures for each individual engine, and it will occasion no surprise when it is stated that they almost invariably differ, owing to the slight and accumulative inaccuracies of machining, from those laid down by the designer.

In practice, the collars of the valve spindle are left, approximately, ¾ in. wider than required, in order to allow for the necessary adjustment. An alternative method adopted in some works is to machine the collars to the finished size and to insert thin steel washers between the valve head and the collar. There is a distinct objection to this, however, in that there is ever-present danger of such washers going astray or being wrongly assembled when the engine is overhauled at the sheds. It is clear that such a state of affairs would at once nullify any initial accuracy in the valve setting.

Fig. 24 shows the correct position occupied by the valve head and spindle when the engine is on front dead-centre—assuming inside steam admission—and from which it will be observed that the distance C of valve head from front of cylinder $= A + FP - (FL + FH)$. For instance, on the engine in question, where measurements showed that

$$A = 8{\cdot}997 \text{ in.} \quad FP = 1{\cdot}873 \text{ in.} \quad FL = {\cdot}25 \text{ in.} \quad FH = 2{\cdot}622 \text{ in.}$$
$$C = 8{\cdot}997 \text{ in.} + 1{\cdot}873 \text{ in.} - ({\cdot}25 \text{ in.} + 2{\cdot}622 \text{ in.}).$$
$$C = 7{\cdot}988 \text{ in.}$$

On the same basis, with the engine on back dead-centre, as shown in Fig. 25,

$$D = A + FP + B + BL - (E + FH).$$

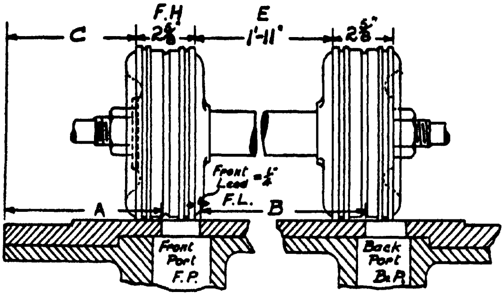

FIG. 24.

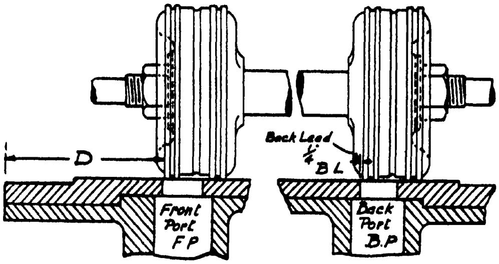

FIG. 25.

In practice, the valve spindle with its front valve head assembled, is inserted into the cylinder and the whole coupled up to the motion. With the engine set on front dead-centre, the distance of the valve head from the front cylinder face is measured by means of a micrometer depth gauge. The measurement is then compared with the calculated dimension. It will be readily appreciated that it is by no means an uncommon occurrence for the valve setter to find, after he has taken the aforesaid measurements and then proceeds in succession to take similar measurements with the engine in back dead-centre, and also for both centres in back-gear, varied discrepancies between the actual and the calculated figures. Slight inaccuracies in machining, play in the motion parts and reversing gear are among the contributing factors to these variations.

It is then his object to minimize these differences by averaging the discrepancy, thereby dividing it up between the two centres as follows:

	Calculated.	Actual	Difference.
Forward Gear :			
Front dead-centre .	7·998 in.	8·198 in.	+·200
Back dead-centre .	10·498 „	10·758 „	+·260
Backward Gear :			
Front dead-centre .	7·998 „	8·188 „	+·190
Back dead-centre .	10·498 „	10·728 „	+·230
Average difference . . .			+·220

The spindle is now disconnected, taken out of the cylinder and the valve head removed. The spindle is then put between the lathe centres and the collar reduced in thickness an amount equal to the average difference between the actual and the calculated position of the valve head on the spindle, as shown in the preceding table.

Assume for the moment the front valve head collar has been adjusted so as to bring the valve head to its desired position. The distance between the ports being variable, it is obvious that E (distance between valve heads) must also vary in proportion. For example, if dimension B after measurement is found to be 8/1000 in. wider than designed, then E dimension must be increased a like amount, or otherwise the back lead will be increased or decreased accordingly. Thus, on the same engine where B = 25·008 in. as against the designer's 25·000 in. and the back lead required ·25 in. with E designed to be 23·000 in., the

$$\text{Distance } D = 8{\cdot}997 \text{ in.} + 1{\cdot}873 \text{ in.} + 25{\cdot}008 \text{ in.} + {\cdot}25 \text{ in.} \\ - (23{\cdot}008 \text{ in.} + 2{\cdot}622 \text{ in.}) = 10{\cdot}498 \text{ in.}$$

To obviate the necessity for an individual calculation for each engine, the table (Fig. 26) was compiled in which is given C and D dimensions for all probable variations of A and the front port dimensions. It is of vital importance to ensure that when the front collar on the valve spindle is faced up, the back collar shall be similarly treated to give the correct distance between the two heads. By this means, the accuracy of the back lead is automatically taken care of.

Referring now to the case of built-up piston valves where the two heads are connected by a distance piece, or, as in the American design of hollow valve, by a " thimble," a somewhat different method is adopted. This will be the better understood by referring to Figs. 27 and 28.

Now, since the distance between the two heads is fixed, adjustment of each individual head cannot obviously be then made, but this does not preclude adjustment of the valve as a whole. In valves of this type the heads are built on the spindle with the correct distance between the steam-ports. In the case of cylinders where one liner suffices for the complete valve, the steam-ports can be easily slotted or milled the correct distance apart to a reasonable tolerance, but with cylinders having two separate liners for one complete valve, a different method of ensuring the ports being the correct distance apart must be adopted and is carried out while the cylinder is in course of machining.

TABLE FOR SETTING PISTON VALVES

Standard Dimensions: A= 9 in., B=25 in., E=23 in., FH=2·625 in., FP=1·875 in., FL=·250 in., BL=·250 in

A.	FRONT PORT.									
	1·873 in.		1·874 in.		1·875 in.		1·876 in.		1·877 in.	
	C.	D.	C.	D.	C.	D.	C.	D.	C.	D.
8·997 in.	7·995	10·495	7·996	10·496	7·997	10·497	7·998	10·498	7·999	10·499
8·998 in.	7·996	10·496	7·997	10·497	7·998	10·498	7·999	10·499	8·000	10·500
8·999 in.	7·997	10·497	7·998	10·498	7·999	10·499	8·000	10·500	8·001	10·501
9·000 in.	7·998	10·498	7·999	10·499	8·000	10·500	8·001	10·501	8·002	10·502
9·001 in.	7·999	10·499	8·000	10·500	8·001	10·501	8·002	10·502	8·003	10·503
9·002 in.	8·000	10·500	8·001	10·501	8·002	10·502	8·003	10·503	8·004	10·504
9·003 in.	8·001	10·501	8·002	10·502	8·003	10·503	8·004	10·504	8·005	10·505

WIDTH OF FRONT HEAD

2·622 in.	2·623 in.	2·624 in.	2·625 in.	2·626 in.	2·627 in.	2·628 in.
+·003 in.	+·002 in.	+·001 in.	+·000 in.	−·001 in.	−·002 in.	−·003 in.

Fig. 26.

The first step consists of facing the cylinder face, against which the shoulder of the valve liner abuts, to the correct distance from both the front and rear faces of the cylinder. The actual distance B is then measured by means of a vernier and compared with the drawing; any discrepancy found is then halved and a note taken of it. Following this, the shoulder on the valve liner is faced up to give the correct dimension plus or minus half the aforesaid discrepancy, as the case may be. By this means—with the distance between the valve heads correct—absolute accuracy in both the front and back leads is secured when the valve is placed in its correct position in the liner relative to the ports. This position is determined by the same method described in the earlier stages, but with the exception that there is only one collar on the spindle and that is faced up to suit the adjustment of the valve to the ports.

It may not be inopportune before concluding to refer to two factors which it is advisable to bear in mind when considering the question of valve setting, and which in effect comprise the difference as between conditions in the shops and under working conditions. The first of these is the alteration in valve setting due to wear of the axle-box crown. The effect of this is to lower the engine relative to the axle, thereby moving the valve away from its designed position in the cylinder. In consequence of this it is the practice in some shops to set the valves with the height of the engine adjusted to the mean wear of the axle-box. The second is the expansion—due to heat—of the valve and spindle whilst under working conditions. Of both these factors it is difficult to give any definite allowance, since it is only experience that can give the modifications which they cause. Their results vary both in the different classes of engine and also relative to the conditions under which they are working, but at least it can be said that they certainly are points which it is by no means advisable to ignore.

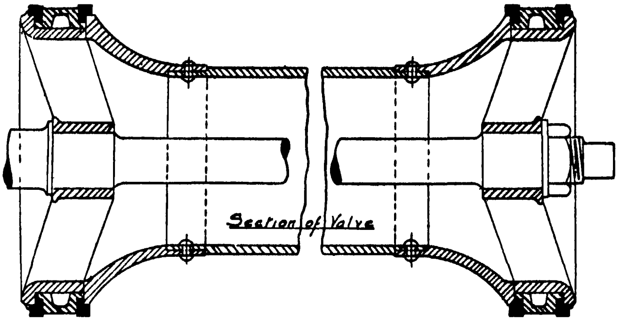

FIG. 27.

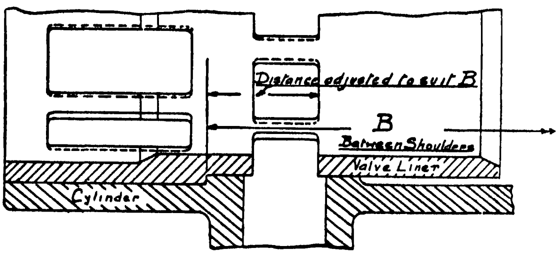

FIG. 28.

Walschaert-Gresley Gear.

The following notes appertain to the work of valve setting on three-cylinder locomotives fitted with this gear, which is now much in use. Inside admission valves are assumed, also " Two-to-one " and " Equal " levers deriving their motion from the front ends of the outside valve spindles. The setting is to be done by equalization of the leads. It should be realized from the outset that the first aim of valve setting is so to arrange the position of the piston valve relative to the valve-gear that the lead, or opening of the port to steam with crank on dead-centre, is as nearly as possible equal, front and back, for all cut-offs. The secondary aim is to equalize the full port openings.

The first operation is to set the driving axle-boxes in "running position" in the horns—an important point which, if neglected, may lead to inaccuracies.

Next, the extreme limits of travel of the crossheads are marked off on the motion-bars, first with connecting rods disconnected and then with these connected. To find the limits in the latter case, the dead-centres of each crank must be found with great accuracy. The wheels are revolved (by rollers or other means) till the crosshead is within ½ in. of the dead-centre required. A pop-mark (A) (Fig. 29) is made on the crosshead to suit a trammel with its other leg on the motion-bar, and another pop-mark (B) made on the wheel to suit a trammel with its other leg on the frame. The wheels are revolved till pop-mark (A) comes to the trammel again on the opposite side of the dead-centre, when a pop-mark (C) is made on the wheel to suit the trammel from the frame, as before. If the wheels are revolved too far, so that pop-mark (A) passes beyond the trammel, a complete new revolution should be made, or the wheels "backed" some considerable way and then revolved forward again, so that all play may be taken up. The mid-point between (B) and (C) is found with dividers and a pop-mark made (D). When this mark coincides with the point of the trammel taken from the frame, the crank is on dead-centre. Both dead-centres are found for each engine and marked on the respective motion-bars, also

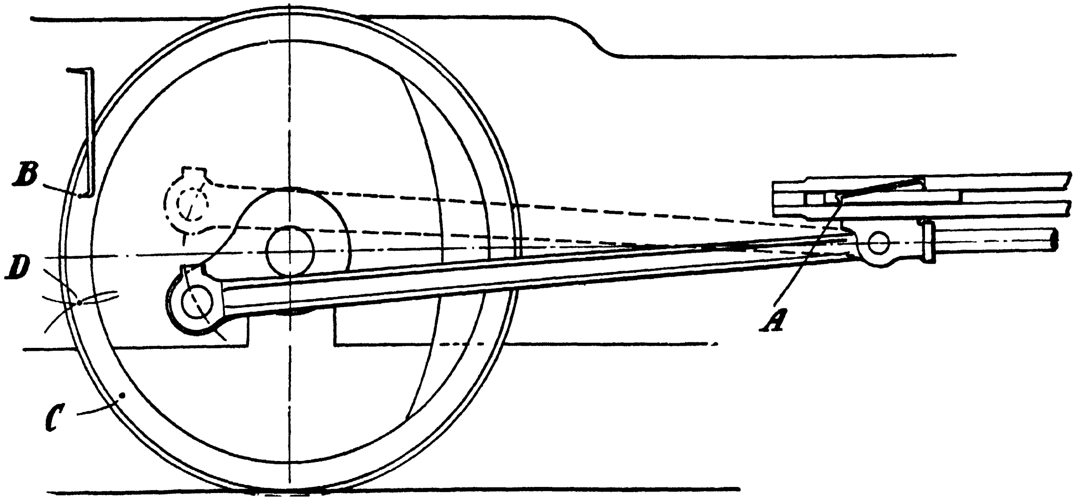

FIG. 29.

on the wheel, as described, the six dead-centres thus being marked on one wheel. The difference between the limits of travel of the crosshead when disconnected and connected gives the clearance in the cylinder.

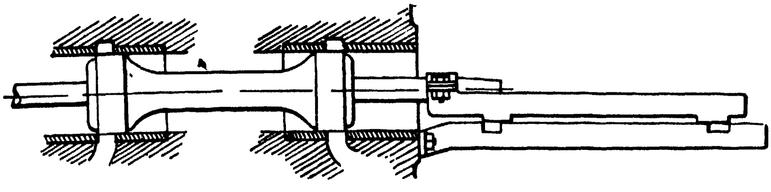

Fig. 30.

For a cylinder 20 in. diameter by 26 in. stroke the clearance should not be less than ⅜ in. at each end.

In the case of the outside steam-chests, practical considerations may make it possible to use ordinary methods of measuring the lead, and in this case templets are used. These templets are set up on the front ends of the valve spindles (Fig. 30) and on the front ends of the steam-chests. They are of flat plate, those mounted on the valve spindles having their edges cut to the longitudinal dimensions of the piston valves, while those mounted on the end of the steam-chest are cut to the dimensions of the ports. The templet on the spindle is edge to edge with that on the steam-chest, so that a complete representation is obtained outside the steam-chest of what is going on inside. The templets require to be "set" with relation to each other; thus when the valve is on the point of opening to front exhaust, the templets should be in a similar position relative to each other. The setting of the outside valve is done with the front steam-chest covers and spindle guides removed and the Gresley gear disconnected. If now either outside engine is set on a dead-centre, the templets on that engine will show the lead.

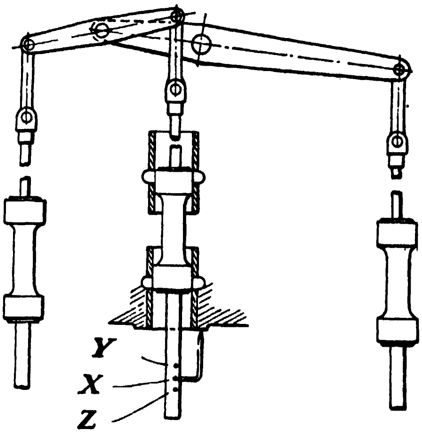

Fig. 31.

In the case of the middle engine, templets are not required. Before the front steam-chest cover is put on, the valve is placed on the point of opening the front port to exhaust, and a pop-mark (X) (Fig. 31) made on the rear end of the valve spindle, which protrudes from the rear end of the steam-chest, to suit a trammel, the other leg of which rests in a pop-mark on the rear face of the steam-chest casting. Knowing the dimensions of the valve and ports, it is a simple matter to put a pop-mark (Y) in front of (X), and another (Z) behind (X), such that when the trammel coincides with (Y) the back port, and with (Z), the front port is about to open to steam. The front and back leads are given by the distances of the nearest pop-mark from the trammel when the crank is on front and back dead-centres respectively.

It may sometimes be found convenient to work from the front end of the cylinder block, in which case the front steam-chest cover and valve crosshead guide is put on, and two new pop-marks made on the valve spindle link to suit a trammel, the other leg of which rests in a pop-mark on the valve crosshead guide. To locate each of these two pop-marks the valve is placed so that the trammel at the back end rests on the pop-marks (Y) and (Z), as the case may be.

The wheels are rotated and the front and back leads of each engine found for points of cut-off of 65 per cent., 25 per cent. and 15 per cent., or thereabouts, both in fore-gear and in back-gear. The maximum port-openings must also be watched. The outside valves must be run over and set first, it being impossible to set the middle valve correctly until the outside valves are correct, as the middle valve is dependent for its own motion on the motion of the two outside valves.

Inequalities of lead or opening are corrected, in the case of the outside engines, by inserting or removing thin washers from between the valve spindle and the valve crosshead at the back end of the spindle; in the case of the middle engine, by means of similar washers between the front ends of the outside engines' washers spindles and their front valve crossheads. Allowance must be made for the expansion, due to heat, of the valve spindles, and especially in the case of the middle valve, owing to the great effect of the expansion of the two outside valve spindles on the position of the middle valve. Any variations which occur must be dealt with so that the average running-point of cut-off is favoured.

CHAPTER XI

Maintenance—Shed Management—Work List—Light and Moderate Repairs—Boiler Examination and Repairs—Washing Out—Grades in Shed Staff—Reports—Shed Tools—Notes on Staff required—Boiler-washing Plant, etc.

Maintenance.

THE maintenance of locomotives in service calls for careful attention. Engines are usually allocated to districts where a shed is provided for their accommodation and where the engines undergo examination after their daily runs, and the necessary running-repairs made to keep them in service. Running-repairs include all the light items that call for attention when examined in the shed, and attached to this is a staff of proficient boiler makers, fitters, etc., competent to perform the repairs called for. After a driver has made his regular examination of the engine on return to shed from duty, he makes a note of all those details that he considers should have attention before the engine is taken out again. These entries receive the attention of the different chargemen, who instruct and supervise their men to carry out the necessary repairs in the best and most expeditious manner. After the work has been done to the details reported, a fitter, or boiler maker, entrusted with the work must initial the book in which the records are made to show that the work has been finished.

Shed Management.

The control of a large running-shed, stabling, say, 100 locomotives, is an undertaking in which considerable ability and skill is required if a maximum mileage is to be secured from each engine before it goes into the shop for general overhaul and repair.

To provide effectually for ordinary running requirements, the shed should be well found in lifting appliances and have adjacent to it a small machine shop equipped with wheel lathes, drilling, shaping and slotting machines, and a few other useful lathes. With such a plant an able manager should keep his engines out of the general shops for periods of four to five years, depending on the class of engine, their mileage and work performed.

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In addition to the drivers, firemen, etc., constituting the running-staff, the superintendent or chief foreman of the shed will require clerks, fitters and turners, boiler smiths, tubers, blacksmiths, copper-smiths and labourers.

The first duty of the official in charge of the shed is to provide the necessary motive power for the service of trains presented by the operating department, and the necessary engines must be ready, in good order and repair, to work all trains to the booked times. In the case of main line specials, notice of three hours should be considered sufficient to enable arrangements to be made, but for short trips twenty to thirty minutes is often all that can be given.

Working List.

A detail which requires the chief's personal attention is the working engine list. In a large shed this is at times divided into three sections, as follows: (1) Weekly list showing the various regular workings for seven days in classes—express passenger, express goods and perishable, fast and slow goods, pilots and shunting, local passenger, etc.; (2) daily list for twelve hours showing revisions from the weekly list, with all specials added; (3) supplementary list containing all alterations made in the daily list, cancellation of trains, modification of starting-times, such as goods and mineral trains being delayed for necessary rest of drivers, and so on.

Training.

Many years of training are required before the responsible position of locomotive driver is attained. After passing satisfactorily a test for eyesight and answering the requirements in physique, etc., the would-be driver enters the service as a cleaner. From that calling he is drafted, should he show the necessary proofs of ability, to act as a fireman on "shunting." Promotion will now largely depend on the efforts of the aspirant to qualify as a suitable man to have charge of a locomotive. He will have to pass a medical examination to convince those in authority he is physically fit, and substantiate his knowledge of the road and the mechanism and management of locomotives by submitting himself for test at the appointed times.

Clerical Staff.

The clerical staff of a running-shed is employed in dealing with correspondence appertaining to engine failures, casualties and staff matters, the drivers' daily returns and tickets, mileage, coal and water consumption, engine repairs and records of examination, stores, wages, etc. The whole represents a mass of work needing intelligence and care in its disposal.

Fitting Staff.

The fitting staff are responsible for all running-repairs being dealt with satisfactorily and to time. The chargemen should endeavour to get everything done as expeditiously as possible to obviate friction among the staff and facilitate the departure of engines at their booked times.

The repairs undertaken in a running-shed may be classified under four heads, as follows: (1) " Heavy " repairs, varying according to the miles run, etc.; (2) " moderate " repairs, which will depend largely on the nature of the service on which the engine has been engaged; (3) " light " or shed repairs requiring only casual treatment; (4) boiler repairs.

Heavy Repairs.

These are influenced by the mileage made by the engine since its last overhaul, and when undertaken will certainly necessitate its being withdrawn from service for five or six weeks, depending on the class of engine and nature of work on which it has been engaged. The wheels of both engine and tender will need re-turning, axle-boxes will have to be refitted, steam-ports of cylinders faced up, valves and pistons examined, slide-bars adjusted, motion overhauled, etc. Further, the eccentric sheaves should be removed from the crank-axle to enable the latter to be thoroughly examined; all the boiler mountings should also be inspected and tested.

Moderate Repairs.

These may be taken as those occupying a week or so to carry out. They would include examination of injectors, valves and pistons, changing springs, rejointing steam-pipes, etc.

Light, or Shed, Repairs.

These refer to those items booked by the driver, after he has made his regular examination of all the assembled parts of the engine, which he considers necessary to be done before it is taken out again. These entries receive the attention of the fitting and boiler-making foremen, who give instructions to their men regarding the best and most expeditious manner of executing the repairs. The details vary and may involve attention to almost any part of the locomotive, such as brake-blocks requiring to be changed, springs defective, glands blowing, valves leaking, etc. After attention has been given to the details reported, the fitter or boilermaker entrusted with the work must sign " off " the book to show the work has been done.

Boiler Repairs.

With the high pressures now used it is essential that the boiler of a locomotive should be kept in a perfect state of repair. Foremost among details liable to give trouble are the fire-box stays, especially those at the level portion of the fire-box, where the heads on the inside are constantly in contact with the fire. As these are worn off, the stays must be replaced with new ones and fresh heads formed. In some cases a weekly examination of the fire-box by the leading boilermaker is ordered, when all the side stays are regularly sounded with a hammer for the detection of any broken ones; this should be undertaken when the boiler is empty, and notes made in a book kept for the purpose.

After a boiler has been running for some nine months, or for about 25,000 miles, it is advisable to remove a few of the lower tubes to enable cleaning to be undertaken, and at the second " sifting " it is usual to take out nearly half. At the third " sifting " the boiler will probably require thorough cleansing, and this will necessitate the withdrawal of all the tubes. These will be " scaled " in a rumbler, pieced, and then replaced, after which the boiler should be tested by hydraulic pressure of 1½ times its working pressure, the test being witnessed and certified by the foreman and chief boiler inspector.

The stated periods for examination, etc., vary on different railways, but by some it is ordered that a boiler must be tested before it has been in service five years, and thereafter be subjected to hydraulic test every three years.

Leaky Tubes.

A large number of engine failures are to be traced to leaky tubes. In some districts bad water is the cause of trouble in this respect; deposit accumulates so rapidly that the spaces between the tubes get filled with dirt, and overheating results; or the overweighted tubes " sag " at the centre, with consequent leaky tube ends. The presence of dirt to this extent is best detected by sounding the tube-plate with a hammer. Plenty of washing out and frequent blowing off are the best precautions to take at sheds where dirty water has to be used. Tube ends burnt thin, too, often give rise to leaks.

In a large shed a gang of " tubers " is now usually employed for renewing tubes; these men are promoted to this special work from boilersmiths' assistants, having received a good experience in fire-box repairs whilst following that calling.

Washing Out.

The effectual washing out of boilers is most important and considerably affects their efficiency. Each engine should have a " wash-out " day every week, and care should be taken that the operation is properly performed. Carelessness will result in accumulation of dirt in the water-spaces, on the tubes and over the crown of the fire-box. These deposits will act as non-conductors of heat and prevent the boiler steaming well, although extra fuel may be consumed. Priming, too, is often caused by a dirty boiler, and delay may ensue from this and the attendant evil of lubricant being flooded out of the cylinders and valve chests. After a boiler has been washed out it should be inspected by the leading boilersmith, who should satisfy himself that all the loose dirt has been removed.

In some running-sheds it is the practice to wash out and refill the boiler with hot water, in which case steam is raised and the engine returned to the road more rapidly. When this is done the hosepipes should be of a very substantial character, and flexible metallic hose is much used for the purpose. The water-tanks of the engines should also be periodically washed out, lads being sent in to clear away any matter which may have gathered round the feed connection orifices. Engines fitted with " pick-up " arrangements often suffer from accumulations of fallen leaves, etc., which have been blown into the water-troughs.

Miscellaneous Work.

The blacksmiths' work appertaining to a running-shed consists chiefly in repairing and adjusting brake work, straightening guard-irons, shortening or lengthening eccentric rods for the fitters, repairing fire-irons, prickers, darts, etc., attending to couplings and straightening buffer-beams, etc.

The copper-smiths will mainly be called upon to attend to steam- and water-pipes and connections, braze on flanges, and renew air and vacuum-brake pipes; they are also required to re-metal or line big-end brasses, axle-boxes, etc.

A rough duty is performed in some sheds by a gang of " joint-makers." These men primarily make steam- and water-joints, but also renew brake-blocks, take out blast-pipes and burn them clean, thus removing the deposit which, by adhering to the orifice, reduces its diameter and thus causes waste of fuel by excessive draught; they also attend to faulty sand-boxes and fittings, uncouple and couple engines and tenders, pack regulator glands, and assist in stripping engines for heavy repairs.

The term " semi-skilled " is generally applied to those men deputed to repair engine and tender foot-boards, renew bricks, fire-arches, etc.

Stores.

The stores are in charge of a head storekeeper, who keeps account of all receipts and issues; he is responsible for the correct issue of lubricating oil, waste, etc., according to the specified allowance per engine for, say, a 100 miles' run. There are usually at least three grades of oil stored for general use; engine or lubricating oil for the axle-boxes, motion, etc., cylinder oil for the valves and pistons, and burning oil for the lamps, etc. Superheater engines will also require special oil.

For local and shunting service the oil supply is usually calculated on the mileage and number of hours the engine is actually working, shunting engines in goods-yards being reckoned at 6 or 8 miles per hour.

The storekeeper also has charge of all the hand tools, taps, dies, reamers, etc., and must record the loan of any of these to the men on a slate or in a book, making sure of their return in good condition.

It is good policy for the head storekeeper to confer with the foreman fitter and boilermaker every fourteen days or so, and take stock of the stores account to see what items require replacement. Copper piping, white metal, metallic packing, brushes, springs, boiler tubes, brake-blocks, fire-bricks and clay, etc., demand careful survey.

In some sheds a good system is in vogue whereby no issues of renewals are made from stores without a printed " request " signed by the foreman and accompanied by the old article for inspection. Files in particular should be dealt with in this manner.

Petroleum oil has entirely superseded tallow for cleaning purposes; it is much cheaper and has not the detrimental action on the varnish and paint often resulting from the use of tallow.

In like manner sponge-cloths have taken the place of waste on many railways, and are systematically dealt with in a suitable laundry. They are tied together in bundles and dispatched in large waterproof bags to the laundry, whence they are returned in similar manner for reissue after washing. To replenish the stock and provide for wear and tear, one or two new cloths are allowed each driver and fireman daily, and they must return the dirty ones to stores before new ones are issued to them.

Odd Grades.

Fire-lighters or steam-raisers have to attend to the lighting up of fires in all engines required for service during the time they are on duty, and must also watch all the engines standing in steam as spare, etc., keeping up the water-level and doing other necessary work. Bar boys usually receive their instructions from the fire-lighters as to engines of which they are to clean down the tube-plates, renew the fire-bars, and so on.

Another grade found in many running-sheds are the "shed-labourers," a useful class of workers assisting the fitters and boiler-makers on their various jobs, lifting engines, attending to hot boxes, etc. They are also employed in cleaning up the pits and shed, loading up ashes, drying sand in the furnace, and sifting it before use. From these men a number are often selected for attachment to the breakdown gang, accompanying the accident train to derailments and other mishaps.

Tube sweepers are specially deputed to sweep tubes, an operation required to be performed more or less frequently, according to the coal burned. Clean tubes are necessary to secure a free-steaming engine and, further, neglect of the tubes will possibly result in the ends being burnt away.

Other specially appointed labourers are the coalmen employed in stacking the coal as it comes in, and also for loading on to the engines. The work is usually paid for by contract at a fixed rate per ton. After a stack has been built to the specified dimensions it is customary to whitewash it all round, or at least at the corners, so that any disturbance of its bulk can be readily detected.

Any "fogging" or signalling during fog required to be done in the shed sidings is usually arranged by the shed foreman.

Running-staff.

Referring now to the running-staff, we include the engine cleaners, as it is from this grade that the firemen are invariably appointed. Youths join at the ages between 16 and 21 years, with the very meritorious ambition of eventually becoming drivers; the rigorous sight and stature tests, with other examinations, however, throw many out. The cleaning is performed in gangs, and each is responsible for its allotted number of engines per day or per night as the case may be.

"Not to be moved" boards should be conspicuously exhibited at the back and front of each engine being cleaned as a precaution against its being moved. Similar boards are also used when any fitter or other workman is underneath.

Young men of approved physique and character are promoted from cleaning to act as firemen, in which capacity they fill casual vacancies and also provide the necessary relief at stations where the ordinary men take rest. The spare fireman receives a permanent appointment in time, and eventually qualifies for driver, commencing his duties in this capacity as a spare or shed driver.

One other class of employee should be mentioned, viz. the call-boys or messengers, whose duty it is to warn drivers of their booked times at all hours of the night; they also act as general messengers for the office. From call-boy to cleaner, from cleaner to fireman, and from fireman to driver represents the three stages many occupants of the footplate have passed through in their long and honourable career in the railway service.

The following may be taken as a specimen of the report which should be sent to headquarters by a running-shed foreman on the occasion of a locomotive going into the shops for general repairs.

Report of Repairs:

Required to Engine No. ——.—Boiler, outside to be examined; bad leakage of steam from beneath lagging-plates, all wash-out plug-holes to be re-tapped and mud-hole joints renewed; badly grooved; inside to be examined, all incrustations to be cleared out.

Fire-box to be examined: bottom portion of fire-box sides reduced in thickness, tube-plate cracked in both top corners, fire-hole ring leaking, rivet heads so much reduced as to require renewing, front corners of foundation ring leaking, renew rivets, roof bolts to be renewed and top of fire-box cleared of incrustation.

Stays to be examined: bottom rows to be renewed, heads badly reduced, slight bulging of plate at lower portion of left side; brick-arch studs to be renewed.

Tubes to be examined: new tubes required, tube-plate fractured at both top corners; throat palm stays require renewing, heads being reduced.

Smoke-box to be examined: side plates very thin, drawing air; new door required, being bulged at bottom and drawing air; new chimney wanted; engine steaming badly.

Ash-pan to be examined: side plates thin, both dampers require renewal and gear to be overhauled.

Safety Valves to be examined and readjusted: 10 lbs. light; valves and seatings to be faced up.

Steam Pressure Gauge to be examined and tested.

Boiler Mountings to be examined: water-gauge cocks, whistles, steam, sand and blower valves, steam-heating valves to be thoroughly overhauled.

Regulator to be examined: head and valves to be faced up; regulator blows through; internal cone joint and steam-pipe to be tested.

Injectors to be examined and cleaned out: waste much water; internal delivery pipes to be changed, choked up inside boiler, difficulty in working injectors.

Steam-pipes in smoke-box to be examined and tested by hydraulic pressure: bottom flange requires re-brazing.

Pistons to be examined: heads and rings to be renewed, slack in cylinders, rods to be trued up, crossheads to be re-metalled and refitted.

Cylinders to be examined and re-bored: badly worn lubricators to be overhauled or changed; drain cocks want renewing.

Steam-ports to be examined and faced up.

Slide-valves to be examined and renewed: very thin: valve spindles to be trued up; sight-feed lubricators to be examined and overhauled.

Glands to be examined: all metallic packings, bushes and neck-rings to be renewed; compression springs to be examined and renewed, weak.

Motion to be examined and overhauled: all loose pins to be renewed, slide-bars to be trued up, eccentric sheaves to be examined and refitted on crank-axle, straps to be examined, liners to be renewed and straps closed; reversing screw to be examined, knocks in screw; reversing shaft to be examined, knocks in brackets; motion shakes badly when running at high speed.

Crank-axle to be stripped, thoroughly cleaned and examined for defects: crankpins to be examined, left outside driving crankpin to be renewed, loose in wheel.

Connecting Rods to be examined: big-end bolts to be renewed and holes reamered out, bolts work slack; big-end and small-end brasses to be examined and renewed.

Coupling Rods to be examined: bushes to be renewed, slack in rods.

Axle-boxes require renewal: bad knocking in guides causing engine to oscillate when running at high speed.

Framing to be examined: bolts to be renewed in driving rubbing pieces; all loose rivets and bolts to be renewed; motion-plate loose on left side.

Cab and Splashers to be examined and repaired: all loose rivets to be renewed.

Springs to be changed and weights readjusted, as engine rides roughly.

Wheels to be examined: several spokes cracked through in right driving wheel; tyres to be examined, thin, and require renewing; left trailing wheel tyre slack, retaining-rivets having worked loose.

Axles to be examined: leading bogie axle reduced $\frac{1}{8}$ in. below standard owing to having been heated and galled.

Brake Gear to be examined and repaired: air-brake to be changed, present pump being slow in supplying air; triple valve needs changing; all pipes to be examined and cleaned; driver's valve to be changed; brake pistons to be examined. Vacuum-brake ejector and steam-brake combination to be examined, slow in blowing up to 20 in. of vacuum. Train-pipes to be examined, and all unions to be tightened up. Steam-brake cylinder to be examined, rings blow through. Vacuum-brake cylinder to be examined; roller rings require renewal and cylinder ball-valves to be changed. All flexible vacuum pipes to be changed.

Tender Repairs.—All tyres require to be turned up. Brake work to be examined and thoroughly overhauled. Axle-box brasses to be renewed. All springs to be changed and tender weighed for adjustment on balancing table. Water pick-up gear to be examined and repaired. Tank water-register gauge to be examined; out of order. Tank leaks badly at trailing end; all loose rivets to be renewed. Hand-brake screw and nuts badly worn, to be changed.

Useful Tools in Shed.

The following are some handy tools that will be found very useful in the various operations necessary in a running-shed. A fitter also requires to make a few special tools to assist him in executing his work in an efficient manner.

To remove main steam-pipes and steam-chest covers from smoke-boxes it is often necessary to split the nuts down vertically in the manner shown in Fig. 1, as they are apt to get "burnt" or corroded on the studs. If the studs are broken they will require to be drilled out carefully, and new studs put in, screwed to a tight fit. For removing and screwing in studs, a stud-setter is an almost indispensable tool, though with skill and care two ordinary nuts tightly locked may be utilized for the purpose.

When in a confined position, it is at times a difficult task to cut an iron nut from a stud without damaging the thread, and this sometimes means the renewal of the stud. On the other hand, a few small screw-die nuts of different sizes will assist in jobs of this description and are useful for running down studs and bolts which have been damaged or when they prove too tight a fit for new nuts. A good method of making die nuts is to get a square bar of good tool steel nicely softened and have it faced and cut off in a lathe to a suitable thickness. Four small holes are drilled to act as cutting-edges, as shown in Fig. 2; but before drilling the larger centre hole to tapping size these smaller holes must be plugged with pieces of soft iron. The drill will then be able to run true, and the plugs furthermore assist the tap to cut a good thread to the proper size. After tapping the thread, the soft iron plugs can be removed, and the cutting-edges formed on the thread finished off with a smooth file. These little appliances are almost indispensable in a running-shed, for in taking off cylinder-covers in a hurry, as is often needful, the stud threads are frequently damaged and a die nut can be requisitioned to remedy the defect. In taking down big-ends for examination it is a common occurrence to bulge the thread in knocking out the bolt; in such a case a die nut is used to re-cut the thread.

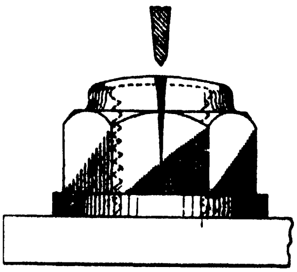


FIG. 1.

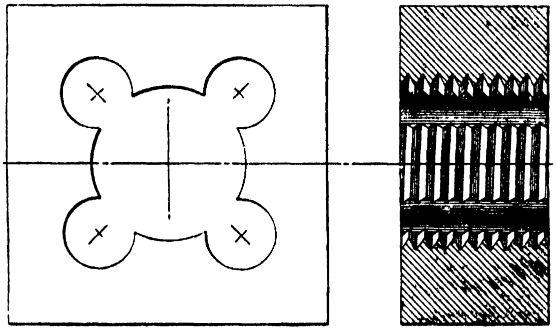


FIG. 2.

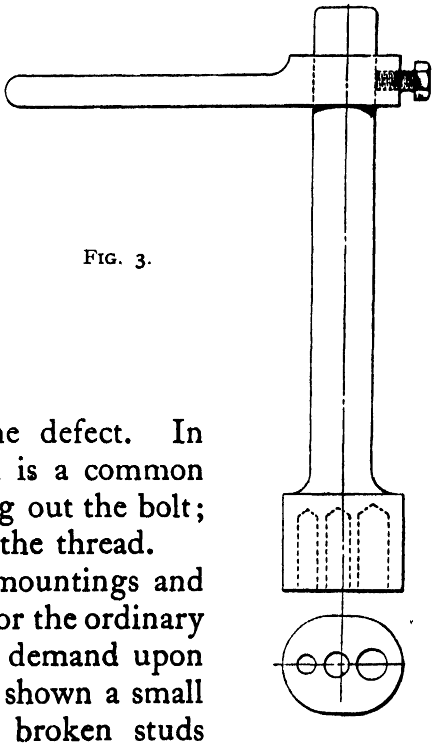


FIG. 3.

Drilling out broken studs on boiler mountings and fittings placed in a position not accessible for the ordinary ratchet brace drill-post and tackle makes a demand upon the fitter for a special tool. In Fig. 3 is shown a small drill-post that can be used to drill out broken studs ranging from ⅜ in. to ⅝ in. The foot of the post is well drilled out to enable it to be attached to seatings where studs are standing ½ in., ⅝ in. and ¾ in. high on the boiler face-plate, and the arm can be attached in any position to suit the convenience of the operator. A tool of this type has been found especially handy in drilling out broken studs in boiler face-plate injectors, which are attached to face-plates in a vertical position. One great advantage is the small space occupied by the base of the post; the appliance is also very light and suitable for packing in the fitter's tool-bag.

Notes on Shed Staff and Procedure.

One fitter and one mate will maintain 6-8 engines in running order. The number of boilermakers required will, of course, depend on the quality of water used; on an average, one boilermaker can maintain 20-30 boilers, whilst one " tuber " and assistant will be required for 15-20 boilers.

Typical Break-down Gang.

One fitter, one tool attendant, two men for jacks, two men for packing, one steam-crane driver and one guard. Total, eight men.

Washing Out Locomotive Boilers.

This operation should be carried out at stated intervals, its frequency being determined by the quality of the water used. With water of average scale or sludge-forming tendency, the following periods may be taken as representative practice:

The most important expresses, 600 miles-800 miles.
Other expresses, 800-1000 miles. With treated water, 1200 miles.
Suburban tanks, goods and shunting-engines, after six days' running.
Where water of excellent quality is available, *e.g.* in some parts of Scotland, washing out only becomes necessary at intervals of 2-4 weeks.

In a working day of eight hours a boiler washer and mate can properly wash out the average number of three engines, assuming that their work is divided between passenger and goods engines.

In sheds where engines are washed out cold, the wash-out water should be delivered at a pressure of from 50 to 60 lbs. per sq. in., otherwise the water has not sufficient force to help the rods effectively to remove the scale lodging between the tubes, stays, etc. Definite time allowances, ranging from three hours for small tank-engines to five hours for a 4–6–0 or 4–4–2 express, should be laid down for cooling, after the steam has been blown off and water let out. This will prevent leakage troubles which would occur from a too rapid rate of cooling. Mud-plugs should not be withdrawn until the pressure gauge registers zero.

Excessive contraction is prevented by washing out with hot water. Further, by this method, engine availability is increased. A modern 4–4–0 engine should be out of traffic approximately ten hours for a cold wash-out, whereas four hours at most will suffice with the hot-water apparatus. The disparity increases with the dimensions of the engine concerned; a ten- or twelve-wheeled engine will lose about thirteen hours from traffic for a cold wash-out, but only five for hot. On the other hand, the washer is not able to manipulate his rods effectively when large quantities of steam are rising; and further, certain forms of scale are more easily removed cold than hot; for these reasons, in sheds where hot washing-out is customary, a monthly cold wash-out should be arranged for each engine.

Mud-plugs should always be carefully cleaned and greased before replacement, care also being taken to ensure their entry without cross-threading. All mud-hole door joints should be carefully examined before being passed for further use.

The quantity of water used in washing out a boiler is in part determined by the delivery pressure, and may in extreme cases amount to twice the quantity of water normally contained in the boiler at " half-glass." The average amount used is from 1·50 times the latter quantity.

Tube Sweeping and Arch Cleaning.

These operations should always be carried out whenever the engine is stopped for washing out. In addition, engines working the principal expresses, and all those burning soft, friable coal, should have the tubes swept and arches cleaned down daily. Engines fitted with self-cleaners, which should always be operated in a thorough manner at least once per trip, should need little, if any, attention in the shed as regards tube cleaning.

Compressed Air.

Compressed air can be used for many purposes in the shed; besides tube cleaning it may be utilized for chipping and scouring hammers, drills, tube expanders and for raising steam in " dead " engines, and forms a convenient motive power for portable cylinder-boring, crankpin turning, port-facing and kindred machines.

Fire-bars.

The life of the individual fire-bar varies approximately from three months to two years. It is greatest in the case of shunting-engines and least in passenger express locomotives; the clinkering propensities of the coal used will have considerable influence on the life.

Engine Availability.

In normal British working 18-23 per cent. of the total engine stock is under repair at one time, and therefore unavailable for traffic. This figure varies very considerably and has been reduced by the introduction of mass production features and the adoption of intermediate service repairs.

Coal Stacking.

One man will stack twenty tons of coal per day, inclusive of " walling." Piecework prices range from 7d. to 9d. per ton, according to the locality. Bituminous coal used for stacking may usually be taken to run out at 45 lbs. per cub. ft. of stack, and Welsh coal at 55 lbs. per cub. ft. A section of an average coal-stack 1 ft. square at the base and 9 ft. high will equal approximately one-fifth ton.

Feed-water and Priming.

An average locomotive boiler contains about 1250 gallons of water and evaporates about 7500 gallons per day. The average impurities found in locomotive feed-water in England are about 2 lbs. per 1000 gallons. Of these, chlorine and sodium salts remain in suspension in the water, and do not deposit on the tubes, barrel and fire-box plates in the form of scale. As the quantity of water evaporated increases, the concentration of these two impurities becomes greater and greater until finally that point of concentration is reached when foaming or priming commences; then water changing and blowing down is necessary.

When chemical analysis reveals the presence of chlorine and nitrates together in large quantities, the water will be of a corrosive nature and should, if possible, be avoided.

Boiler-washing Plant.

The hot-water washing-out plant illustrated (Figs. 4 and 5) is the well-known White's system already fitted at a number of depots on the London & North-Eastern Railway. The apparatus has for its object the distribution from a central plant to various points in the shed of three services, one to allow for boiler water to be blown out into the system, one to distribute pressure hot water for the usual washing-out process, and a third service of clean hot water for filling locomotive boilers as required. The chief advantages of such a system are firstly the reduction of time over the ordinary cold-water process increasing the availability of locomotives; and secondly, the facility with which boiler water can be changed when desired.

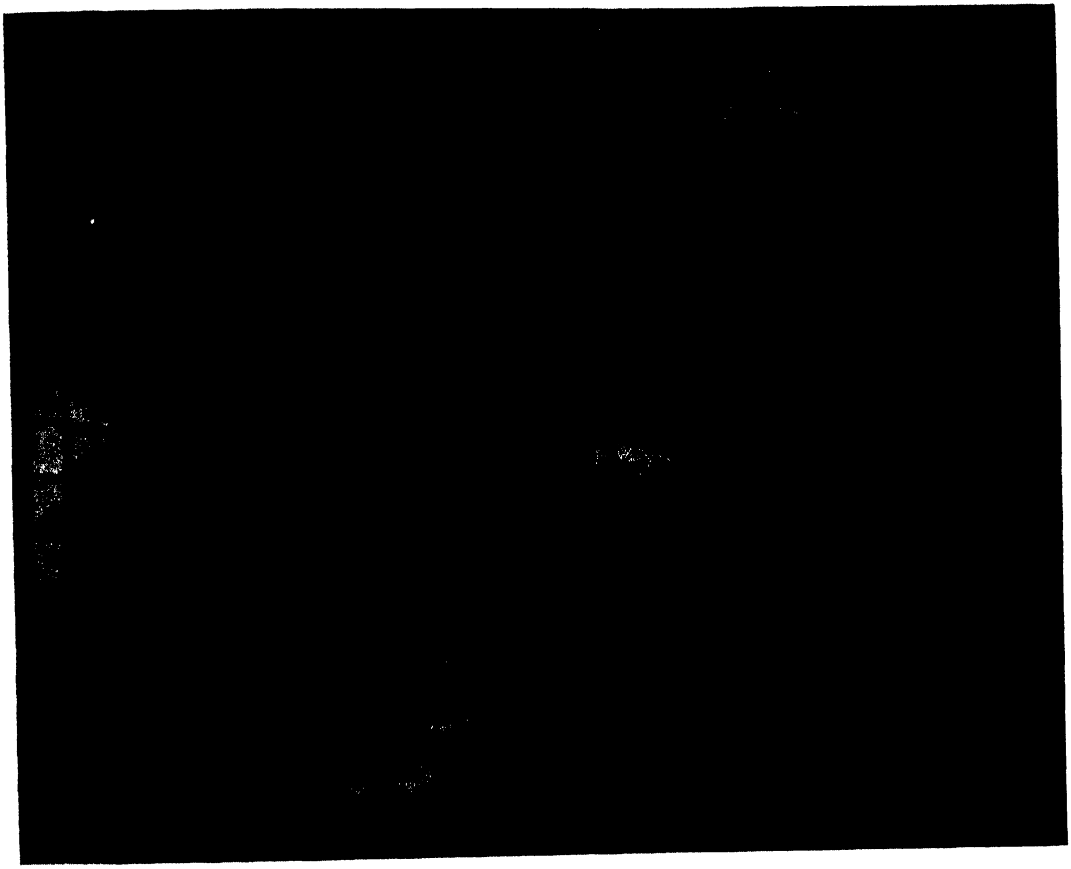


Fig. 4.—Boiler-washing Plant.

The lay-out of the plant is shown in Fig. 6. The building containing the main plant is situated between the main running-shed and the smaller shed. The hot-water services are arranged to be available throughout the twelve roads of the main shed, by six sets of distributing overhead pipe lines positioned intermediately so as to each serve two roads, and containing in every line nine triple-drop connections spaced 45 ft. apart. The smaller shed is equipped by two lines serving three roads, and each line has five triple-drop connections similarly spaced. The central plant is arranged on the double-tank system, and is sufficient to handle six locomotives under each of the three different services—that is, six can be blown down, six washed out, and six filled at any one time. Thus it can be normally said that the plant handles six locomotives on any of the possible phases of the hot-water washing-out process. The plant is one of the largest installations in the country. The size was determined on the basis of a 24-hour day, and its great capacity was decided on to cope with the very large number of engines stationed at this depot. The heavy traffic makes it desirable that engines should be available promptly and give a maximum earning capacity.

Fig. 5.—Washing out Boiler.

The central plant is housed in a brick building, conveniently placed for its duty. There are two cylindrical hot-water tanks of 15,000 and 20,000 gallons capacity, which act as reservoirs for the washing out and for the filling water respectively. Water from these tanks is delivered under a pressure of 60 lbs. per sq. in. to the pipe lines by two horizontal duplex compound Worthington steam-pumps, one connected to each tank. Water blown back from locomotives is treated in the following way. The blow-out pipe line enters a separator (or filter), and the water first strikes a baffle, breaking it into a spray. Steam evaporated from the water on reduction of pressure is led away and utilized in the heater by condensation and feeds into the filling-tank. The remaining blow-down water passes through the filter containing broken coke to the wash-out tank. Sediment drains into a sludge-tank, which is blown to waste as required. The level in each tank is maintained by automatically controlled valves. Two locomotive type stationary boilers are set adjacent to the tank-house, one being in use and the other spare. Their function is to provide steam at a pressure of 100 lbs. per sq. in.

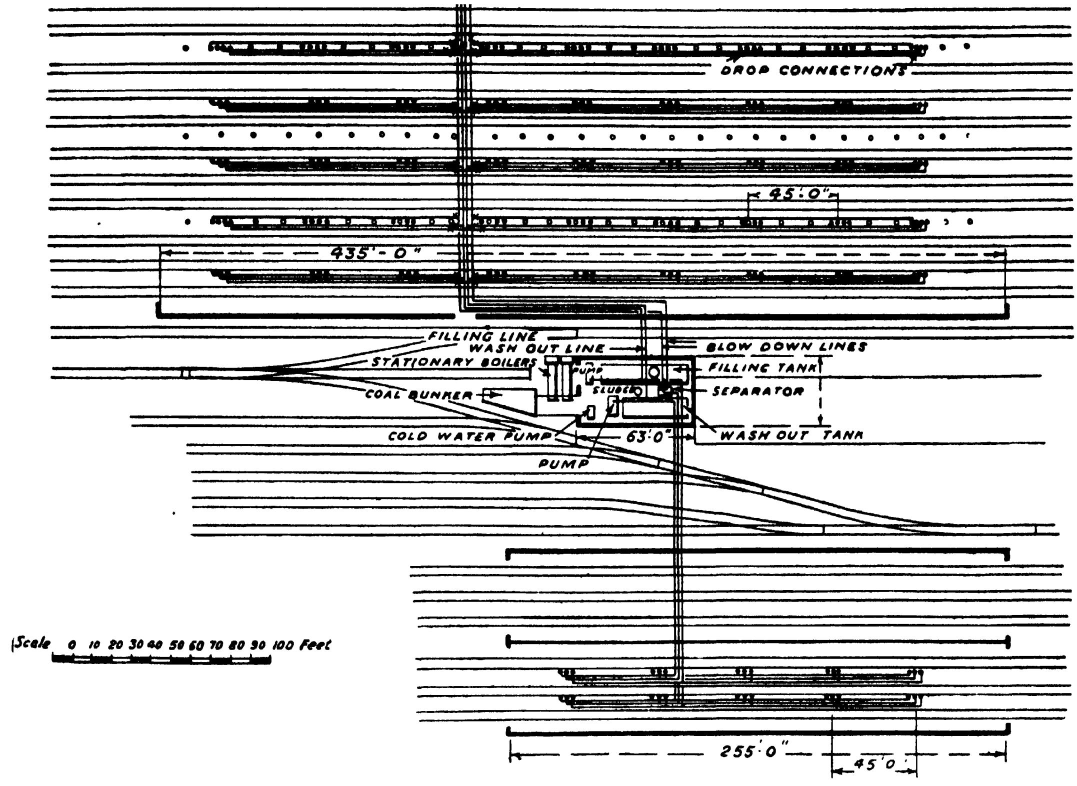


FIG. 6.—LAY-OUT OF BOILER-WASHING PLANT, STRATFORD LOCOMOTIVE DEPOT, L. & N.E. RAILWAY.

for the two pumps, and to act as an auxiliary source of heat for the main tanks. The whole of the exhaust steam from the pump passes into the tanks. Both exhausts can be concentrated on one tank if necessary.

The triple services mentioned are distributed by three overhead mains serving the small shed, and by four mains serving the main shed. In the latter case the blow-out main is divided. From each drop connection on the wash-out and filling services, near the individual control valves, a small-diameter pipe connects to a small return main to the tanks, ensuring a complete circulation of hot water to every working point and maintaining the temperature. The two steam-pumps, when no work is being done, are running light at a low speed, maintaining a pressure of 60 lbs. per sq. in., and a slow circulation of water. The opening of any valve in the shed on the wash-out or filling lines temporarily releases the pressure in the mains and brings into operation the regulator of the pump concerned, governing the steam admission valve. The pump then takes up the load until the valve concerned is shut, when the regulator closes to its former position and the pump slows down again. Both regulators are set to maintain a pressure of 60 lbs. per sq. in. in the mains, and each pump is of a sufficient capacity to maintain this pressure with a delivery of 30,000 gallons per hour. In case of emergency it is arranged that each pump can pump from either tank and supply both services.

The working temperature of the water is maintained within predetermined limits, and they have been fixed as high as is practical in the circumstances. The maximum temperature of the wash-out water used on this plant is 180° F., and that of the filling water is 210° F. The temperatures are automatically limited by thermostatically controlled valves. In the case of the wash-out water the thermostat is placed in the pump delivery and is set so that, should the temperature rise above 180° F., a normally closed diaphragm valve admits cold water to the pump suction, adjusting the temperature of the actual water delivered, whilst retaining the temperature of the tank water. The prescribed temperature limit for the filling water is obtained by placing a thermostat in the filling-tank, which is connected to a normally open diaphragm valve admitting live steam to the tank until the temperature reaches 210° F., when the thermostat comes into operation and closes the valve. These thermostats can be adjusted to suit requirements. The pump regulation previously mentioned and the temperature control described enable the plant to work automatically.

The tank-house also contains a 13-H.P. motor-driven centrifugal pump supplying the cold-water washing-out service. This unit has a capacity of 13,200 gallons per hour when pumping against a pressure of 43 lbs. per sq. in. The original washing-out mains have, with certain alterations, been used for this service. This pump obtains its supply from the mains at a positive pressure, and a by-pass has been arranged for use in emergency so that washing out can still take place during a break down of the pump.

At the same time as this work was undertaken rearrangements were made to the water supplies. Originally water from several sources was mixed in the service reservoir located close to the Stratford running-sheds and having a capacity of 110,000 gallons. The pressure of water available for any purpose was strictly limited to about 13 lbs. per sq. in. The service to this tank was formerly interconnected with the general water supply of the locomotive works adjacent, which is derived partly from two wells and partly from the Metropolitan Water Board mains. The well waters are of inferior quality. Town water only is now fed to the tank and thence to the water-cranes and the hot-water washing-out plant, and it is now the only water used for filling locomotives. A new 8-inch town water main has been laid to the service tank, ensuring an adequate supply of water at all times for every purpose. The mixed water has been separated and is used for both cold- and hot-water washing purposes, but if emergency arises the other source can, in addition, be drawn upon. The Stratford locomotive sheds have now a full supply of water at adequate pressure for all purposes and sufficient for all contingencies.

For the successful operation of this hot-water washing plant it is necessary for locomotives, after the fire is dropped, to come into the shed with a steam pressure of at least 40 lbs. per sq. in. and blow down with as little delay as possible. If this is done, the greater part of the heat in the boiler water is recovered. The time occupied is about half an hour, and the operation exercises a considerably cooling influence on the boiler, so that hot washing out can be started immediately. Connection is made to the drop connections by a length of 2-inch armoured hosepipe with unions which are suitable for fixing to the various hydrants. The time taken for the whole operation of blowing down, washing out, refilling, and steaming varies with size of the locomotive. For a large engine of the " Sandringham " class (4–6–0) this is a minimum of six hours, which compares very favourably with the twelve hours under the previous low-pressure, cold-water method.

Savings that are made possible under this scheme deriving principally from the Economical Boiler Washing Co.'s plant are availability of engines, fuel for lighting up, and a distinct improvement in the internal condition of the boilers with its contingent advantages. A saving of water is made, as the water in the locomotive boiler is filtered and used again for washing-out purposes, and also as the make-up water used is inferior water, which, while not being suitable for boiler-feed, is satisfactory for washing out.

CHAPTER XII

Combustion—Fuels used—Solid and Liquid—Composition and Heating Value—Hot Feed—Mechanical Firing—Pulverized Fuel

Combustion.

To secure the best results from any fuel burned in a locomotive, it is advisable to know something of the elementary principles of combustion, and utilize these in practice. Roughly, the coal of ordinary quality supplied to British locomotives requires some 20 lbs. of atmospheric air per lb. to secure satisfactory combustion, and on the correct admission of this air to the fire-box and admixture with the combustible elements of the fuel, much depends for satisfactory results. With different grades of coal the methods of firing must be varied to suit them—for instance, with " hard " steam-coal (Yorkshire, Durham, etc.), a light, thin fire made up at frequent intervals with small amounts, will ensure most steam, but with " soft " coal (Welsh), it is best to build up a heavy, thick fire, and rely on the maintenance of this for satisfactory generation of steam.

The diagram (Fig. 1) shows, in a graphic manner, the general direction of the gases in a locomotive boiler: working under ordinary running conditions, the blast from the exhaust pipe, up the chimney, draws from the smoke-box a portion of its contents ; to supply the partial vacuum so caused, the air rushes in at the damper and fire-hole, that through the former passing through the fuel and supplying the oxygen requisite for combustion, and that through the latter regulated chemically to saturate those gases that have not been able to obtain their proper equivalent through the damper.

Composition of Fuel.

The chief components of any fuel useful for the generation of heat are carbon and hydrogen, and as these, when effectually consumed with the requisite proportions of oxygen, give off known quantities of heat, it is easy to ascertain the heating value of any fuel from its chemical analysis.

For the combustion of 1 lb. of carbon, 2·66 lbs. of oxygen are required, and as atmospheric air contains but 23 per cent. of the latter, it follows that nearly 12 lbs. of air are required for the consumption of 1 lb. of carbon.

One lb. of hydrogen requires 8 lbs. of oxygen, or, approximately, 35 lbs. of air. In actual practice twice this is usually allowed to compensate for the fact that so much of the air admitted through the fire-grate does not get intimately incorporated with the fuel.

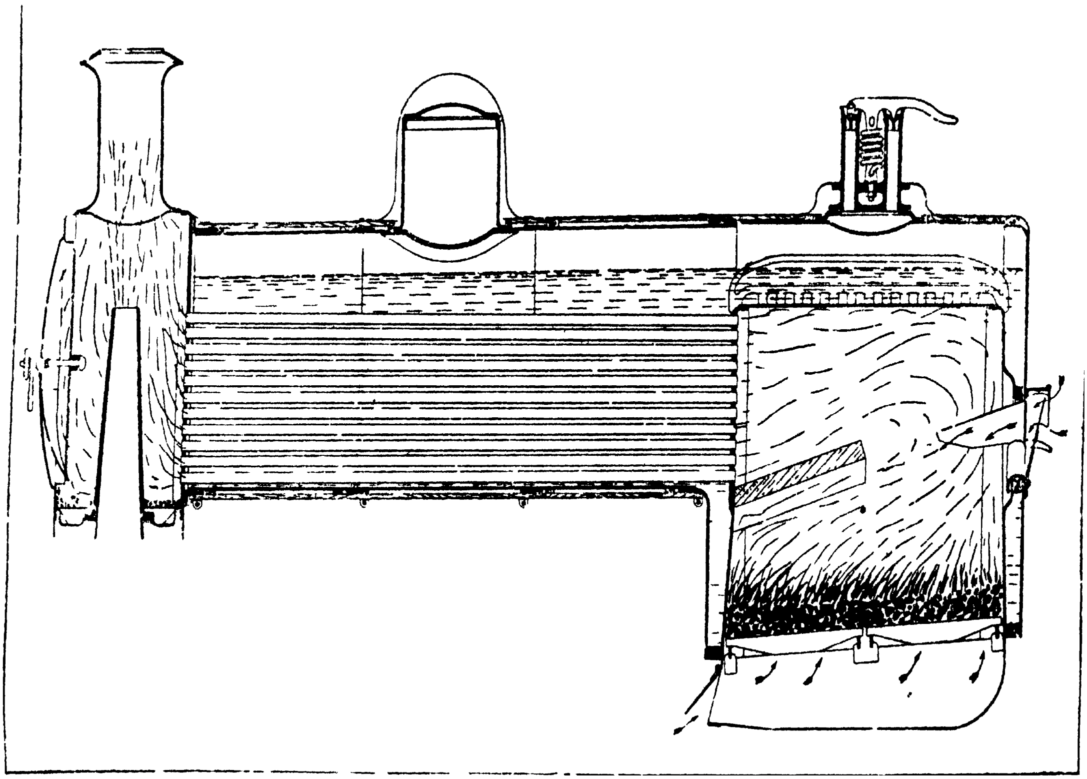


FIG 1 —COMBUSTION DIAGRAM

Anthracite.

Anthracite contains more carbon and less hydrogen than any other coal. Owing to its low volatile matter it ignites less easily than other types, but burns with a short flame and very little smoke, and does not soften or cake. It is a strong, non-coking fuel giving high temperatures. Semi-anthracite coals, such as "hard" or Welsh steam-coal, form a transitional group between the anthracite and bituminous coals. They are divided into two types, according to the amount of volatile matter, those having from 8 per cent. to 12 per cent. form the celebrated first-class Admiralty coals, and those with from 12 per cent. to 15 per cent. the caking steam-coals, which include the second-class Admiralty coals. Their special value is in their low ash content, high calorific value, smokelessness, and free burning qualities. Steam-coals should be free burning—that is, they should not cake strongly, nor break down on heating, and thus impede the draught through the fire. They should have a high calorific value, and the amounts of ash and sulphur should be low.

Other Coals.

Coking coals should yield a strong, hard coke, suitable for use in metallurgical purposes. Coals from several areas satisfy these requirements, notably Durham, South Wales, Yorkshire, and Kent. Gas-coals suitable for gas manufacture cover a fairly wide range. Usually bright in appearance and soft, the essential properties are a high volatile content, and yield, on carbonization, a good domestic coke, less dense and not so hard as metallurgical coke. Many coalfields produce excellent gas-coals. A typical example of a Yorkshire gas-coal is Barnsley " soft," from Houghton Main Colliery. Splint coal is a dull, hard substance, which breaks with a peculiar splinty fracture. Because of its hardness and low coking power it is chiefly used (especially in Scotland) for direct use in blast-furnaces in place of coke.

The following table gives approximate steaming values for the chief locomotive fuels. As the actual efficiency of every sample of coal will vary, only the " general " figures can be given, these will, however, be sufficient for purposes of comparison.

Grade of Coal.	Per cent. of Carbon.	Per cent. of Hydrogen.	Per cent. of Sulphur, Ash, etc.	Approximate Evaporation.	
				Theoretical: lbs. of Water per lb. of Fuel.	Actual: on a Locomotive.
Average Samples:					
Welsh . . .	92	3·5	4·5	14	9
Yorkshire . . .	79	5·0	16·0	13	8
Lancashire . .	76	5·0	19·0	12½	7½
Scotch . . .	80	5·0	15·0	13	8
Pennsylvanian . .	90	2·5	7·5	13	8
Indian . . .	60	3·0	. .	12	7
Australian . . .	68	2·5	. .	10	6½
South African . .	50	3·0	. .	8	5

NAWAB SALAR JUNG BAHADUR

Economy by using Hot Feed.

Secured by feeding a boiler with heated water.

Temperature of cold water assumed to be 60° F. and the boiler pressure from 130-200 lbs. per sq. in.

If heated to	The approximate gain in fuel will be
100° F.	Over 3 per cent.
150° F.	„ 8 „ „
200° F.	„ 12 „ „
250° F. (by aid of exhaust injector)	„ 16 „ „

Temperature Notes.

Approximate temperature of a fire as indicated by its appearance:

Red just showing	About 1000° F.
„ dull	„ 1300° F.
„ bright	„ 1800° F.
Orange, deep	„ 2000° F.
„ bright	„ 2200° F.
Yellow	„ 2400° F.
White	„ 2600° F.
Intense white heat, as of a furnace	„ 2800° F.

Approximate coal and water consumption of British locomotives per 100 *miles:*

Large passenger engines	35 cwts. of coal and	3500 gals. of water.
Small passenger engines	25 „ „ „	3000 „ „
Small passenger tank-engines	37 „ „ „	4000 „ „
Express goods engines	55 „ „ „	3700 „ „
Mineral goods engines	60 „ „ „	3700 „ „
Colliery collecting engines	80 „ „ „	7000 „ „

The above figures will be found to be fair averages from practice with engines of approved design and using suitable coal.

Although coal is the common fuel for locomotives in this country, wood and petroleum are extenisvely employed in districts of the Colonies where these are more accessible and plentiful than coal. For wood it is more difficult to give values which would be of practical service, as the suitability of woods for fuel purposes vary so much. The heating value of a fair sample of dry wood suitable for fuel, containing about 4 per cent. of carbon, is given as approximately 7250 B.T.U., against Welsh coal, 15,000 B.T.U., and Durham, 14,500 B.T.U., so that in practice it would require probably twice as much wood to do the same work as coal.

Liquid Fuels.

Regarding oils used as fuel, the subjoined table has been given by authorities as the heating value in British thermal units:

	Specific Gravity.	Flash Point.	Water Evaporation from and at 212° F.		
			In practice.	Theoretical.	B.Th.U.*
Creosote oil . .	1·075	180° F.	12·5	17·4	16,810
Coal-gas tar . .	1·220	150° F.	11·6	15·6	15,070
Russian astatki . .	0·900	200° F.	14·0	21·0	20,290
Texas oil . . .	0·935	150° F.	13·5	20·3	19,610
Borneo oil . . .	0·960	170° F.	13·5	20·3	19,610
Green oil (tar product)	1·115	220° F.	12·7	17·3	16,710
Oil-gas tar . . .	1·070	120° F.	12·8	17·8	17,200

* The B.Th.U. is calculated as—Evaporation (Theoretical) × 966.

Coal-firing.

In a thick fire of hard coal the air drawn through the grate is first brought into contact with that portion of the coal lying on the bars, with the consequence that this lower layer burns briskly—giving off heat which is partially absorbed by the upper layers of " green " coal, the lighter and volatile constituents of which are distilled off, producing smoke, a dull fire, and little steam. With poor quality coal the formation of clinker is considerably augmented by heavy firing, and it is desirable to run with as light a fire as possible when using inferior coal.

Failure in maintaining steam may be attributed to the engine being overworked owing to the weight or booked speed of the train being in excess of the engine's capabilities; any difficulty in this direction, however, should, if possible, be anticipated before commencing the trip. On most railways the engines are classed and their loads specified. The tubes should be properly cleaned so as to get all the possible heating effect from them, and the fire should be clear and bright without clinker to obstruct the air passing through the fire-bars and deaden the fire. The boiler should be well filled with water, and the steam pressure raised to just below blowing-off point before the starting-time of the train, so that all the energy possible is ready for the work.

When the engine pulls out of the station the fire-door should not be opened nor the injectors worked until the train is moving fairly fast, and the expansion gear is " notched up " into approximately its running position. If necessary, a little more fire may be put on then—from four to six shovelfuls—the coal being broken up to about the size of cobbles and well spread over the bars, with a larger proportion at the sides and corners, whence it will gradually shake down into the centre of the fire-grate. The broken up coal will ignite and give off heat more readily than if put on in large lumps.

Whilst on the run, the coal should be thrown in at regular intervals with due regard to the road, keeping the fire thin about the centre of the grate, and thicker along the sides and at the back; a good plan is to make a complete circuit of the fire-box in from three to four applications when firing.

Want of steam may be due to carelessness on the part of the fireman by firing too heavily or putting large lumps of coal on a nearly " dead " fire, so that it takes some time to ignite, or by allowing clinker to accumulate upon the bars. The formation of this latter may sometimes be traced to the ash-pan being nearly full of cinders which obstruct the passage of air.

As already mentioned, coal, if put on in excessive quantities, will not burn at once, because when first thrown into the fire-box it absorbs a large quantity of heat, swells, cracks, and gives off gas before igniting. If the fire is not hot enough to raise the coal to the required temperature rapidly, it will continue to give off gas for some time, with the result of imperfect combustion smoke; this latter will cause soot to be deposited in the tubes, which in turn will retard the passage of the heated gases generated by the fully ignited fuel and absorb some of the heat. On the other hand, dullness in steaming may be due to air inlets in the smoke-box, through bad joints, etc., reducing the partial vacuum there, and detracting from the draught upon the fire. Another cause may be the blast-pipe and chimney not being perfectly true or concentric with each other, so that the full effect of their correct combustion is lost. This is indicated by the smoke and steam striking on one side of the chimney, and can be accurately proved in the shed by wiping the interior of the base of the chimney round with a piece of oily waste, and noting the appearance after the exhaust of a beat or two has passed through. These defects cannot be rectified by the driver, but should be booked at once when detected, so that they may be put right by the shed staff, as a good " steamer " will never be secured until they are. To counteract the deficiencies in steam production as much as possible the feed must be " nursed," and only applied at favourable times, and the driver must take every opportunity to economize in consumption of steam on down grades and other points where power can be saved.

If all precautions are taken, and it is still found impossible to keep up the pressure and water-level, then it may be assumed that the load is too great for the engine with its small reservoir of steam to draw from. This trouble is one that will not be so common in the future as it has been in the past, the modern practice being to build the boilers of locomotives of a size more in accord with the power they are expected to develop.

It is a common expedient, if an engine will not steam well, to brick up the smoke-box, and so decrease its cubical capacity; the blast then has a much sharper and " biting " action on the fire, increasing the rate of combustion. If such a decrease in capacity, however, be carried too far, small pieces of unconsumed coal from the fire-box will be drawn through the tubes and thrown from the chimney, thus wasting fuel as well as endangering property adjacent to the railway from fires caused by the " sparks." The continual lifting of the fire by a sharp " cutting " blast will wear away the plates of the fire-box above the level of the surface of the fire, and the tubes also will be badly scored, especially if made of copper or brass.

It should be the aim of every engineman to run with as soft a blast as is consistent with good steaming properties, anything sharper than necessary for this, whether produced by reducing the size of the smoke-box or contracting the blast-pipe outlet, is to be deprecated. The latter expedient, the reduction of the blast outlet, will seriously affect the coal bill, as it increases the back pressure, and, therefore, the amount of work the engine will have to do; steam will be wasted in simply overcoming the resistance to escape which that imprisoned in the cylinders encounters after it has done its work.

The fire-grate should receive careful attention on every possible occasion, especially on shed days; any burnt or bent bars should be removed and new ones put in to replace them. All the air spaces between the fire-bars should be as uniform as possible and not too large, as in this latter case the ashes that fall through into the ash-pan will be large and represent unconsumed fuel. The sides, front and back ends of the grate should be looked to, and the bars at these places fitted in " snugly " to prevent as much as possible the access of large volumes of cold air there; the fire-box plates, owing to the presence of water on the other side of them, are much below the temperature at which coal is ignited, and as all the air that enters must be raised to the proper heat before it assists in combustion, it follows that air should be prevented from impinging upon the side plates before it has chemically combined with the coal and fire, and proper combustion has taken place. Some engineers carry this idea to its logical conclusion, and make the sides and both ends completely air-tight by fixing dead plates round the edge of the bars, rigorously excluding all air from entering there.

The proper height for the bars is another important matter which is often slighted; a little difference in this may affect the steaming powers of an engine considerably. It is generally conceded that the rear of the grate should be higher than the front, a slight slope allowing the fire to shake down as the engine runs; this keeps the fire on the move, the air spaces clean, and retards the formation of clinker. When the bars slope, care should be taken in firing, and the back end, especially at the corners, should be well supplied with coal, or otherwise cold air will enter, with the bad effects already mentioned.

Some coals contain ingredients which form clinker when it is burnt; this is a fusion of various matters, and to this the ash, etc., adheres, making a covering which sticks to the bars and prevents air from the ash-pan having access to the fire, which will cause loss of steam, and in extreme cases melting of the bars themselves. When coal of this nature is used, some flint stones, or pieces of broken up firebrick, large enough to remain upon the bars and not fall through to the ash-pan, should be sprinkled over the fire before commencing the day's work ; this is a good precaution, as if clinker does form it adheres to the stones, or bricks, instead of to the bars, and can be broken up and more easily lifted out of the fire-door by means of the " slice."

Other Considerations in Running.

An engine should leave the shed with its ash-pan clean and empty; further, this will require attention at different periods of the day's run, depending on the grade, quality and quantity of the coal consumed and the working of the engine generally. If air cannot get to the fire-grate freely then the fire-bars will become heated, bent, or even melted, as the temperature of the contents of the fire-box is considerably above the melting-point of cast iron; the rush of cold air for combustion keeps the grate in working condition. With shut dampers an ash-pan should be practically air-tight, and although this is not so essential as an air-tight smoke-box it does occur that a tight ash-pan may be of great assistance—as for instance when the fire has been dropped and it is necessary to move the engine whilst hot. This is especially noticeable if the engine has to pass over a cold pit, for then all depends on the closing of the dampers to prevent cold air entering the hot fire-box and tending to cause leakage of stays and tubes.

The fire-door and dampers should be so regulated when running that a proper proportion of air is admitted both above the fire, through the fire-door, as well as below the fire-grate, in order to secure good combustion. The amount of air which it is desirable to admit at the fire-door varies according to the grade of coal burned—the more bituminous samples requiring the most.

The sides and top of the fire-box (more often the latter) and the roof-stay boltheads will frequently become coated with hard deposit, especially when small coal is being burned which has been well watered in the bunker. Similar deposit also accumulates in the fire-box ends of the tubes and over the whole tube-plate, especially when no brick arch is used. This hard deposit can be roughly cleaned off with the "slice," and the tube ends pricked out with the "pricker," after which the roof should be dealt with, using the same tools as much as possible. When the engine is in the shed and comparatively cool, the fire-box plates can be well cleaned; time devoted to this will be amply repaid when running.

Care of Tubes.

When soot is deposited in the tubes, there is a tendency to extinguish the flame from the fire owing to the restricted area offered to its passage, also on account of the reduced temperature of the water surrounding the tubes rapidly conducting the heat away. Tubes should therefore be cleaned out as often as necessary by means of a tube-rod, of, say, $\frac{3}{8}$ in. diameter, having a suitable handle formed at one end and a series of holes provided at the other, into which pieces of unravelled rope—about 6 in. long—are threaded; the rod must be long enough to conveniently pass through the tubes, so that all soot, etc., is cleaned out by its passage, either into the fire-box at one end, or the smoke-box at the other. Manila rope is to be preferred, as it is stiffer and forms a harder brush. Larger tubes will need more strands of rope than smaller ones.

Steam-blower.

This should be kept on whilst the tubes are being swept, to carry the soot away upwards through the chimney, otherwise the operator will certainly suffer; soot may be much more easily removed when the boiler is hot than when cold.

The smoke-flues of superheater engines are best cleaned by steam or compressed air jets, operated from within the fire-box. Suitable apparatus for this work has already been mentioned under the heading of Soot Cleaners (see Vol. I, p. 32).

It is essential that the smoke-flues should be kept clear so that the heated gases may freely pass through them, when not only free-steaming can be assured, but that the elements will be kept hot maintaining a degree of superheat which will be beneficial to the working of the locomotive.

Air-tight Smoke-boxes.

As already noted, an air-tight smoke-box is of more importance than an air-tight ash-pan, and too much care cannot be devoted to this if a good steaming engine is to result. Any leakage in the constructional work of the smoke-box which admits air to impair the vacuum, created by the blast, will minimize the effect on the fire, thereby affecting the combustion and allowing the temperature therein to fall, producing a bad effect on the steaming.

Nothing looks worse about a locomotive than to see its smoke-box front red-hot after a run, due to combustion of ashes having taken place inside by reason of the air drawn in through leaks.

Any leaks detected in the bottom of the smoke-box round the joints of the tube-plate with the cylinders, or where the side-plates are attached to the frames, especially at the corners, is best remedied by a quantity of cement or fire-clay spread over to effectually prevent access of air; this will also tend to preserve the plates from burning. In some cases a layer of bricks and fire-clay over the top of the cylinders is a good precaution, as it prevents hot ashes drawn through the tubes coming into actual contact with the metal, and causing it to be corroded away by burning and chemical action.

Leaky Tubes.

These may be caused by bad firing affecting the steady temperature of the fire-box, such as when a fire is thin and bright, giving off intense heat, a heavy charge of fresh coal is put into the fire-box and a considerable reduction of temperature ensues. The tubes are affected by this before the tube-plate, as they are so much thinner and more closely in contact with the gases, consequently they contract and become comparatively slack in the holes of the tube-plate; water is then forced through the joints by the pressure in the boiler. When a boiler is known to be liable to this defect great care should be taken with it; the fire should be kept well alight and as bright as possible, small charges of coal being put on at each firing, and the fire-door kept as near as possible to its regular working position, and always restored after each opening.

On entering a tunnel or terminal station the dampers will have to be partially, if not entirely, closed. This recommendation should be carefully observed, and a medium, bright fire, sufficient to prevent access of cold air to the tubes, maintained. Various remedies are suggested for leaky tubes, such as putting bran into the water-tank and allowing it to be taken into the boiler with the feed-water. This has been claimed as effective in mitigating trouble, but such a remedy, if used, needs great care being taken with injectors, as if only one is used the other may have its waterways clogged with bran, and may then refuse to work when required.

Other parts of the boiler, such as stays and joints, may give trouble by leaking, and if these defects develop in the barrel or any other inaccessible position, it is quite out of the engine-man's power to remedy, and such mishaps should be reported at once in the shed.

Leakage in the internal fire-box may be very satisfactorily counteracted for the time being, by careful firing—the same as with leaky tubes.

Engines should be moved as little as possible with their own steam whilst hot and after having the fire dropped, as quite a large volume of cold air may be drawn through the fire-box and tubes by the blast, which may cause leakage by the contraction set up in the various joints. For the same reason the injector feed should never be operated after removal of the fire.

Leaky Stays.

These are often caused by the accumulation of dirt or scale between the inner and outer fire-boxes, which prevents the water having free access to them, causing local overheating and consequent leakage; frequent washing out assists to lessen the possibilities of this, but if such leakage persists, the stays will require caulking at their inside ends.

Priming.

This trouble (called " foaming " in America) is due to a percentage of water coming over with the steam as it leaves the boiler. It is very troublesome at times, and may be dangerous. It usually occurs when the water level becomes too high, raising the surface to near the point at which steam is being drawn off. The remedy is obvious: lower the water level. There is, however, another cause for priming not so easily dealt with, which is the unsuitability of water being used for feed. It may be oily or dirty, in which case the water in the boiler should be changed frequently. To reduce priming when running the regulator should be as nearly closed as possible, then the steam allowed to be " wire-drawn " through the small outlet. This will have the effect of throwing back the water and quietening down the surface, when the regulator can be gradually and steadily reopened to the required amount. It is not advisable to open the regulator too suddenly at any time, as it may cause a tendency to prime, especially if the water level is high.

Scum or Blow-off Cocks.

On locomotives working in districts where the feed-water is especially troublesome, scum cocks are sometimes fitted on the boiler or fire-box front at about the water level, to enable the surface water to be blown off at suitable intervals. A similar blowing off of " scum " is often secured in the shed by filling the boiler as full as possible and then blowing off at the safety valves; this will remove much of the troublesome water but may cause disagreeable consequences unless the operation is performed out in the open. When an engine is running and develops a liability to " prime," the level of the water shown by the water-gauge cannot always be entirely depended upon, and it will be noted that it falls very much when the regulator is closed. In these circumstances care should be taken not to run with such a low level that the fire-box crown-plate may be uncovered when steam is shut off. Dangerous results of priming are that the water will work over into the cylinders and, being non-compressible, is liable to cause breakage of the cylinder covers, pistons, etc., so straining the motion, unless quickly released from the cylinder cocks.

Injector Feed.

When working a heavy train, the feed of a locomotive will have to be kept " on " almost continually, in order to maintain the correct water level in the boiler. It is to be noted that it is much easier to keep a constant water level on a fixed steam pressure than to raise either of these again if allowed to fall.

Refusal of an injector to work is a common fault, and is often due to priming, for steam highly charged with water will not operate an injector. Such refusal is usually detected by a rush of steam and water at the overflow. An injector that repeatedly refuses to "pick up" or frequently "flies off" should be booked for examination, as it is more than probable some of the cones inside need attention; if any of these are loose, badly worn, or not in their proper position, good working cannot be secured. Many modern injectors are made with a clack-box in combination, and are also fitted with a stop-cock, by the closing of which any part of the injector can be examined whilst the boiler is under steam. Such injectors are usually fitted to the fire-box front and have internal delivery pipes arranged inside the boiler barrel; these must be kept free from deposit.

After repeated trials at starting an injector it will become heated by the temperature of the steam, and it will be necessary then to allow it to cool down by letting cold feed-water pass through it before it can be "coaxed" into re-starting to feed the boiler. The cooling process can sometimes be assisted by wrapping round it a handful of waste taken from a bucket of cold water.

Stiff Regulators.

If the packing in the stuffing-box of the regulator rod is too tight, or there is a want of lubrication, a regulator will invariably be found to work very stiffly. There should be a lubricating hole in the top of the gland, and if this is looked to now and then sticking should be prevented.

In the case of slide-valve regulators, these get dry at times and may work badly. A little oil introduced with the feed-water helps, but this must be done carefully or priming will follow.

Regulators of the slide-valve type often fail by breakage, which occurs at the pin joint upon the arm of the rod lifting the valves or at the joint connecting the valves to the lifting-rod. If the former fails and the valves cannot be lifted, they will both close the ports, shut off steam, and cause a total stoppage. If, however, the top joint fails and the small valve only will open the ports (the larger valve usually has a lip at the top to prevent it falling off the face when uncoupled) the engine can still be operated and the train moved if not too heavy; then, when necessary to stop, as the regulator cannot be shut, the engine can be put into mid-gear, or even reversed. Further, the brakes can be applied and the cylinder cocks opened to prevent steam accumulating in the cylinders. In the event of an engine becoming unmanageable when running, the best procedure is to let the steam pressure down and so reduce power. A double-beat regulator or any steam-valve may "blow" due to grit getting on to the working surfaces, or there may be a leak at the joint of the regulator-head and steam-pipe. This can be detected by steam escaping from the exhaust or cylinder cocks when the regulator is closed and the reversing lever in full gear. It should be mentioned that sufficient " blow " may allow steam to accumulate in the cylinders, and so start a standing engine if no precautionary measures are taken.

Safety Valves and Pressure Gauge.

These should be frequently examined and tested. In the case of Ramsbottom valves, the connecting links should be looked to, and pins, etc., renewed when necessary, to prevent the loss of the valves and lever should the spring break. The pressure gauge can be checked over by the employment of an additional gauge and comparing the pressure registered by each.

Water-gauge Glasses.

These should be carefully examined and renewed at regular intervals, as the bursting of one on a trip may prove an awkward accident, despite the fact that the column may be provided with a protector, etc.; the automatic valves, too, may fail to act.

When on examination the glass tube has apparently worn thin in the neighbourhood of the gland nuts, it should be taken out and replaced by a new one. Drivers should carry one or two spare glasses with them, cut to the correct length, so that if breakage does occur a new one can be put into position without loss of time. To put in a new glass the top nut of the fitting should be taken out and the old glass removed (this is much easier when the glass is not broken). With ordinary hemp packing, this should be taken out and the passage for the new glass cleaned, the latter being then put in from the top. A short piece of wood of about the same diameter as the glass is introduced above it and the top nut screwed down on this. The glass will then be held down in place, preventing any of the packing working under it and partially blocking the waterway of the column—an event which might cause a false level to be shown in the glass. When the top and bottom glands are both repacked, the piece of wood must be removed and top nut replaced. If cones are used for packing—as they often are now—the operation is much simplified, as the gland nuts will only have to be slacked back, the old glass taken out and the new one put in, the glass being held down as before until the glands are screwed up. In packing the glass care should be taken not to screw the packing nuts down more than is sufficient to make the rubber rings steam-tight around the tube; if screwed too tight they may cause a strain on the tube, so that the slightest expansion by heat, or contraction from cold, will cause it to break. In screwing up the glands it is important to revolve the glass after the nuts are adjusted, to ensure that the packing is not too tight. Care should also be taken to see that the glass is well down in its lower seating, otherwise here again the packing may obstruct the waterway.

In making any of these screw joints, red lead should not be used, as it sets hard and increases the risk of breaking the fittings should these have to be disconnected in a hurry; a little tallow or oil alone should be used.

The glass itself and the elbows, top and bottom, should be periodically cleared of any dirt or sediment by means of the blow-off cock provided for the purpose. It is advisable for a driver to examine the water-gauge himself, and see that all is kept clean and in good working order, as he is the one most likely to be scalded should a failure occur when running; if the cleaning is systematically done it is an easy task. It is particularly essential that columns of the automatic "shut-off" kind should be regularly attended to, as scale from the water in the boiler may clog the moving parts and then, if the glass bursts, they will not act. In addition to the water-gauge column it is usual to provide one or two test cocks, which can be used in case of failure of the column. These must also have attention in the shed—be taken apart and oiled frequently—otherwise they are likely to get set fast and then cannot be opened when required. In running, when dependence is being placed on a single-test cock, this is usually slightly opened so that it can be seen that water comes from it and not dry steam.

Steam-pipes and Connections.

It is most necessary that these should be kept tight and in the best condition, for any leakages will seriously affect the vacuum in the smoke-box. A blowing joint on the front tube-plate where the elbow for the steam-pipe to the cylinders is fixed is a very bad defect. Should it develop when running, the best procedure is to keep the blower on to draw the steam away from the tube-ends and so help maintain the draught on the fire.

Other Defects.

The blower or steam-jet often suffers from the defect of blocked holes in the circular ring arranged round the top of the blast-pipe. This should be examined as a precaution against failure when other fittings of the boiler are inspected. Constant care to remedy small defects tend to much easier conditions when running.

Another detail which must not be omitted is the blast-pipe. If a good steaming engine is to be assured, the position of the blast-pipe relative to the chimney is of paramount importance. If the centre line of this is not true with the centre of the chimney it will be found that instead of a concentric cone of steam being discharged at each stroke of the piston, the exhaust steam will strike the base of the chimney, the blast on the fire will be seriously impaired, and the steaming of the engine correspondingly affected.

Spark arrestors should also be carefully examined when the smoke-box is under inspection, and when washing out the boiler the fusible plugs must be cleaned and checked over to make sure they are not covered with encrustation or scale which would be detrimental to their operation in case of necessity. Mud doors and plugs also require attention.

Faults of Injectors.

Different patterns and makes of injectors develop various troubles at times, but, generally speaking, any of them will be subject to failures, as:

Failure to lift water. A leak in the suction pipe will cause this, and the easiest way to locate the trouble is to blank off the overflow and block up the suction pipe. Then, if steam is admitted, the position of the leak will quickly assert itself and steam blow out at that point. Likewise a bent steam nozzle may be the cause, deflecting the steam jet to one side instead of directing it centrally, or it may happen that the nozzle gets choked, or the overflow blocked, offering resistance to the free exit of steam. Further, if the steam-valve leaks the water in the suction pipe will become heated; and then, when steam is turned on, the vacuum created causes vapour to be given off from the hot water, and this is drawn up the pipe instead of water; an immediate remedy is to throw some cold water over the suction pipe, to cool it. In such cases the steam-valve should be reground as soon as possible.

Will lift water, but not force it. The small passage of the delivery pipe (or tube) may be choked by scale or other impurity which has reached it from the suction filter. Examine the valve to see if this works freely. If the delivery pipe is long and has a number of bends in it, resistance may be set up by dirt accumulated therein, or the back-pressure valve on the boiler may be sticking. Injectors are usually designed to provide sufficient pressure to overcome a certain amount of resistance in the delivery pipe, but if this becomes excessive the apparatus will not work.

Continuous waste at the overflow. An injector will "overflow" if the feed-water gets too high, since the final velocity of the steam-jet is reduced owing to insufficient vacuum in the combining cone, the injector is then unable to deal with the maximum quantity of water at the given pressure; moreover, the condensed steam displaces some of the water, driving it through the overflow spaces in the combining tube. The same fault will develop if the nozzles or tubes become blocked with scale or deposit. On the other hand, if the diameter of the combining tube becomes enlarged by wear more water will be passed than the steam-jet can dispose of, hence the overflow. The above remarks are applicable to the double-tube type of injector which, in addition, is liable to some mechanical faults due to its special construction.

It sometimes happens that water will be lifted by the first injector, but when the handle is turned over to the final position, steam only issues from the overflow. The steam admission to the second injector is too great and must be reduced by modifying the opening of the steam-valve.

All lost motion must be taken up, or the various operations will not follow in the exact sequence necessary for correct action, and the proper working of the injector will be impaired.

Generally speaking, injectors require little more than periodical cleaning from the actual users providing the water for feeding the boiler is good and the treatment meted out to the instrument regular and reasonable.

Internal causes of failure are either the result of incrustation, pitting of the cones and nozzles, or maltreatment in examination or repair. In the simpler makes of apparatus the surfaces of the tubes are straight tapers instead of curved, as theory dictates, and with these the increase of pressure instead of being gradual and continuous will rise abruptly at a particular point and a groove will be gradually formed on the tube. The eddying of the jet will increase round about this point until the injector will finally refuse to work. When this occurs and examination points to the fault being in the apparatus itself, it should be taken down, taken apart, and all parts carefully cleaned and replaced. A 10 per cent. solution of hydrochloric acid is useful for removing incrustation from the nozzles. This does not attack brass or gun-metal rapidly, and is a good solvent for the carbonates usually found in fresh water. The less soluble constituents will generally detach themselves after removal of those which are more readily dissolved. Dilute sulphuric acid will affect some of the constituents of scale, but not all. Nitric acid may also be used, but only carefully, as it has considerable action on brass.

Another good means for removing scale from tubes or nozzles is to heat them in a clean flame and then drop them into a bucket of cold water; the sudden contraction cracks the thin film of scale, which is then easily removed.

When nozzles are scraped, blunt tools only should be used, and with these great care must be exercised to prevent damage to the surfaces and possible enlargement of correct diameters.

Superheater Difficulties.

The general arrangement of a locomotive superheater having been described and illustrated, it may be of service now to mention a few factors involved in the application and working of superheated steam. It may appear that with increase of volume an increase of pressure will result; in other words, " Will the pressure of the steam passing through the superheater be increased when its temperature is raised? " The reply is, there is no increase of pressure so long as there is space for the steam to expand into, as its volume increases due to added heat. When steam is passing through the superheater, the pistons are moving to and fro, and forming, as it were, a constantly expanding steam space.

It is often asked whether it is better to throttle at the regulator and use a late cut-off or to work with the regulator fully open and " notch up " the gear. In this matter there is no hard and fast rule to lay down which can be applicable under all conditions. The fact is that in most cases of superheater locomotives neither procedure can be strictly adhered to; probably it is better to throttle slightly at the regulator and afterwards adjust the gear to suit the road and loads. Slight throttling at the regulator " wire-draws " the steam just enough to get a fall of steam-pressure between boiler and cylinders. In this way the natural flow due to difference of pressure or head will materially assist the steam in its passage through the labyrinth of pipes in the superheater. Slight throttling may also avoid water being carried over from the boiler into the superheater which might result from any sudden rush through a wide-open regulator.

The presence of water in the superheater is very detrimental, as it retards the degree of superheat imparted and may cause cylinder troubles.

The above remarks are not applicable to superheater locomotives, which have the regulator on the cylinder side of the superheater. Similarly, in the case of locomotives having the regulator on the boiler side, an engine may not start quite so readily as an ordinary one after standing, owing to the long length of small-bore steam-piping through which the steam must travel before reaching the cylinders.

It is frequently asked: Why should not the same amount of heating surface generating saturated steam produce a resulting heat value which would do equal work in the cylinders? The reply is: Owing to the fact that saturated steam condenses and forms water on the slightest reduction of temperature or pressure (see Fig. 1A), the heat value of saturated steam is not, in practice, its working value. When steam is superheated—and the higher the degree of this superheat—the nearer the heat value approaches the working value of the steam. This is due, largely, to there being less loss from condensation and greater fluidity, so that the working condition of the steam is much more efficient. In practice it is found that what is lost in density is more than compensated for by the extra heat added in superheating, eliminating the tendency of the steam to condense readily. In other words, the heat expenditure in the boiler is better utilized in the dual capacity of steam generation and superheating, than if only allowed to produce saturated steam, which gives up its pressure on the slightest reduction of temperature, such as when heat interchange with pipes and cylinders takes place.

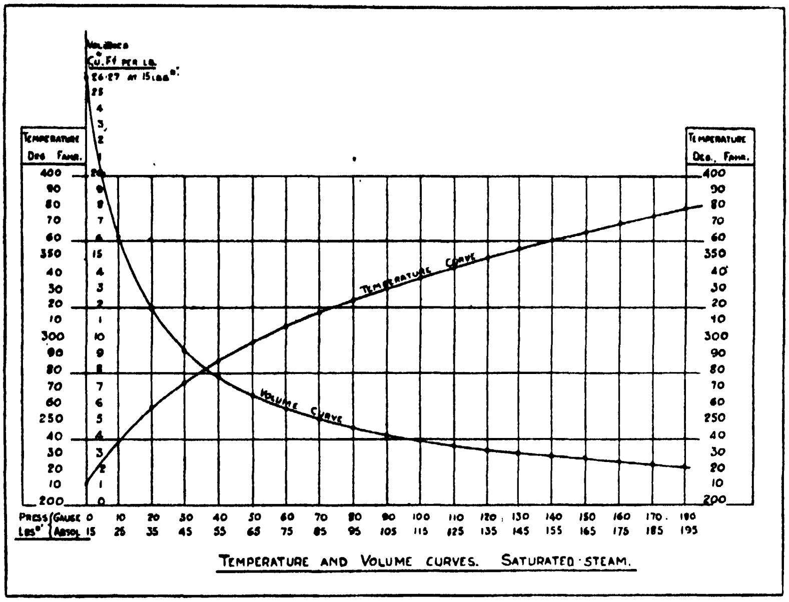


FIG. 1A.

Another question which is often asked is, Does superheated steam give out more power in the cylinder, *i.e.* does it give a "fatter" or "leaner" diagram than saturated steam of equal pressure, etc.? The reply is that theoretically superheated steam for equal conditions should give a "leaner" diagram in the expansion line, as instead of the expansion following the P V (pressure × volume) line it expands according to P V *k* (pressure × volume × *k*) where *k* varies from 1 to 1·3, according as the degree of superheat is high or low. Fig. 2 has been drawn to make this point clear, and is based on terminal volume and readings taken from Marks & Davies' tables relating to superheated steam. The full line shows saturated steam of 160-lbs. pressure expanded according to P V a constant, whilst the dotted line showing superheated steam of the same pressure, raised by 250 degrees of superheat, has expanded according to the tables, but assuming it loses its superheat uniformly, leaving 10 degrees of terminal superheat in the steam. The number of expansions for the saturated steam is 10 fully, while for superheated it is only 7·35, as shown.

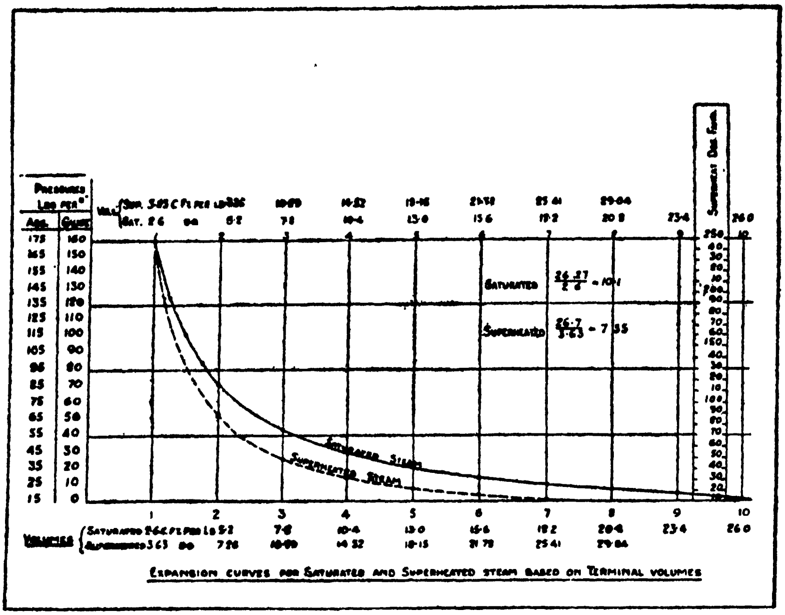
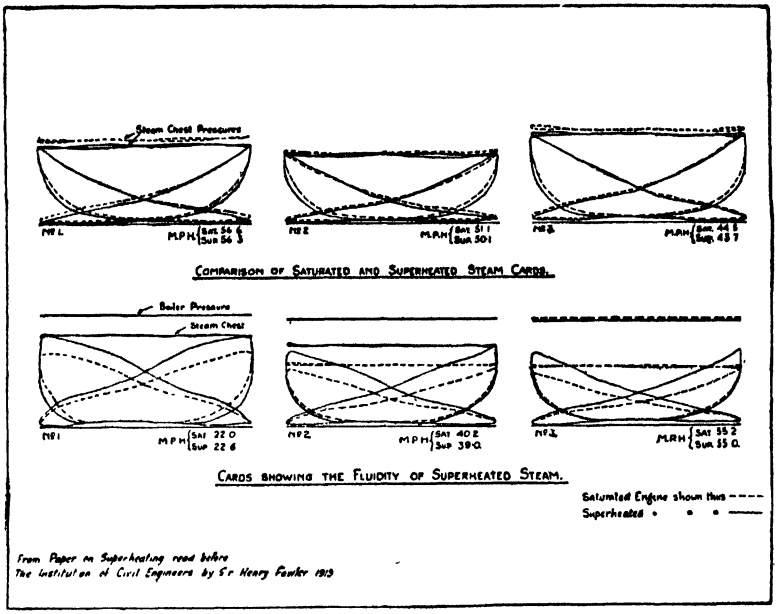


FIG. 2.

Indicator diagrams taken from two similar engines—one being saturated and the other superheated—are given in Fig. 3. These have been superimposed on each other, and show very clearly the points of difference. It will be noted that the saturated steam does not drop in the expansion line so much as does the superheated steam; on the other hand, the exhaust and compression curve is fuller for superheated steam than for saturated. This results in there being no difference in the area of the two diagrams, and therefore in the average mean effective pressure. The lower set of diagrams indicate the greater fluidity of superheated steam.

From the above it is but fitting to ask: Where does the advantage of superheating lie then? It lies almost wholly—though not quite—in the boiler and superheater—in the two-stage generation of the steam, as it may be called. The boiler is made capable of producing steam quicker, and this, with other advantages, may be enumerated as under:


Steam Chest Pressure
No 1.
M.P.H. {Sat 56 6 / Sup 56 3
No 2
M.P.H. {Sat 51 1 / Sup 50 1
No 3
M.P.H. {Sat 44 5 / Sup 43 7
Boiler Pressure
Steam Chest
No 1
M P H {Sat 22 0 / Sup 22 6
No 2
M P H {Sat 40 2 / Sup 39 0
No 3
M.P.H. {Sat 55 2 / Sup 55 0
Saturated Engine shown thus ----
Superheated • • • ——

COMPARISON OF SATURATED AND SUPERHEATED STEAM CARDS.

CARDS SHOWING THE FLUIDITY OF SUPERHEATED STEAM.

From Paper on Superheating read before
The Institution of Civil Engineers by Sir Henry Fowler 1913

FIG. 3.

(*a*) Steam is generated quicker on less coal and water consumption by utilizing a portion of the heating surface to add extra heat to the saturated steam produced, distending its volume but making the steam less liable to condensation.

(*b*) Priming is avoided, as any small amount of water carried over into the superheater is readily converted into steam there.

(*c*) Condensation in steam-pipes, valve chests, and cylinders is largely avoided, owing to the heat reserve in the superheated steam—thus reducing the " missing quantity."

(*d*) Practically no more steam is consumed in the cylinders (although the boiler produces steam at a great rate), which results in the boiler not being forced so much.

(*e*) If it is required to "press" the engine the efficiency of the superheater is increased, because the higher the superheat the easier the engine superheats and the greater the volume of steam produced. This is the exact converse of the saturated steam locomotive, which, when pressed, has a great tendency to prime (or carry water over), and the higher the steam pressure the less the volume of steam produced.

(*f*) Practice has shown that saturated steam locomotives when converted to superheating have their power value enhanced, while the maintenance costs are very little, if any, higher.

Mechanical Stokers.

With the increase in size of locomotives, naturally, the amount of fuel burned in a given time has also increased, and engines are now running, performing services and requiring boiler power which hand-firing would be quite unable to meet, consequently mechanical stokers are being used. For a fireman to spread a ton of coal per hour over a grate of a locomotive fire-box is no mean performance, and, under the best conditions possible, to handle twice this amount reaches the limit of human endurance. Locomotives are actually running which require four times this amount to keep the steam pressure steady, so that it is not difficult to understand the necessity for some mechanical assistance. Fig. 4 gives the arrangement of apparatus for mechanical firing the boiler of a heavy freight locomotive for India. The coal, prior to being loaded on the tender, is passed through suitable screens to secure a satisfactory grade of fineness, in order to enable the mechanism to easily deal with it.

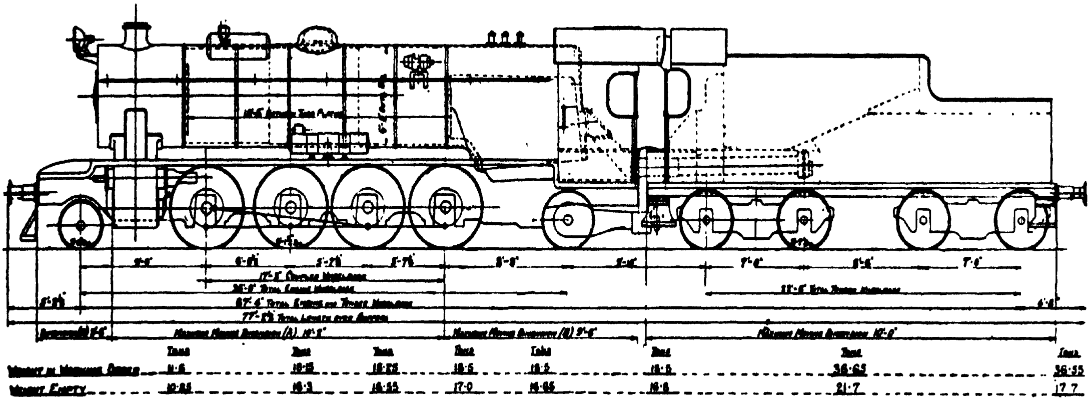


FIG. 4.—2-8-2 FREIGHT LOCOMOTIVE, "XD" TYPE, H.E.H. THE NIZAM'S STATE RAILWAYS, FITTED WITH BOOSTER AND MECHANICAL STOKER.

The mechanical stoker shown in diagram form (Fig. 5) consists of a conveyer and trough in the bottom of the bunker of the tender (Fig. 6), which delivers the coal through a connection to the distributing head at the fire-door. The conveyer is operated by a small steam-engine, which ensures a continuous delivery of fuel to be distributed over the fire-grate. With such a firing device a steady fire is kept without the necessity of opening the fire-door, and if carefully regulated a uniform head of steam can be readily maintained, with good combustion and a minimum of smoke at the chimney. There are several modifications of these stokers, but the one illustrated is a simple and easily attached device. Fig. 7 shows the footplate, including valves and connections for the mechanical stoker, of an Australian locomotive.

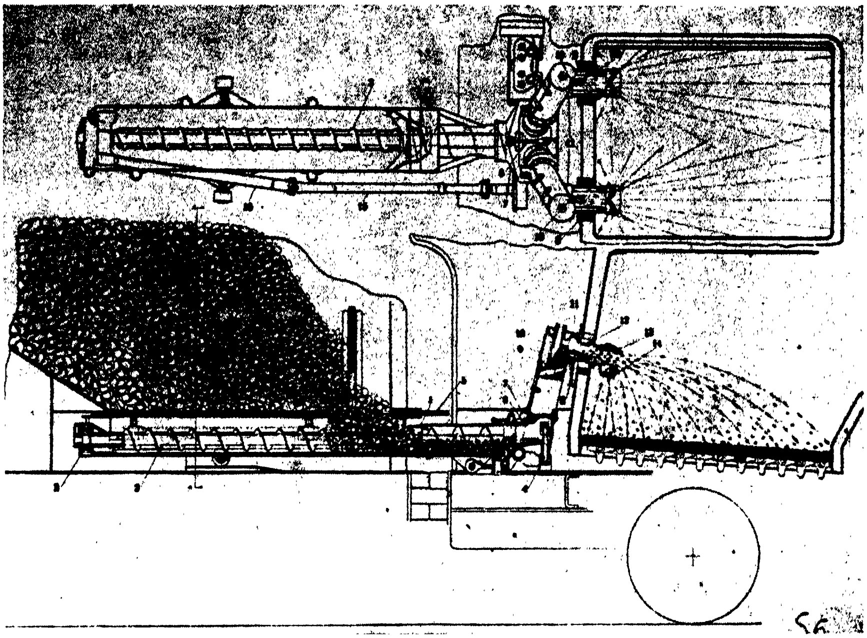


FIG. 5.—DIAGRAM OF MECHANICAL STOKER.

1. Coal crusher. 2. Spur gear driving feed-screw. 3. Feed-screw. 4. Flexible mounting for feed-gear. 5. Tender footplate. 6. Regulating shutter. 7. Base of vertical elevators. 8. Orifices for distributors in fire-box wall. 9. Elevator screw. 10. Fuel outlets. 11. Distributor hoppers. 12. Steam jets. 13, 14. Mouths of distributors. 15, 16. Driving shafts. 17. Pushers.

Oil-firing.

In countries where petroleum deposits occur, oil fuel has to a large extent supplanted coal or wood, as both of these are, as a rule, all but non-existent in such localities.

Oil Fuel arrangements.

In cases of oil fuel burning, the oil-tank generally occupies the space of the coal-bunker, and is provided with warming coils, taking steam from the boiler, a special filling man-hole, and valves for controlling the supply to the engine. The latter are sometimes arranged to automatically shut in cases of derailment, collison, etc.

To successfully use oil fuel, the fire-box of a locomotive needs an arrangement of fire-brick to be built in it, to ensure the proper combustion of the oil, the latter being injected into the furnace by a steam atomizer, or burner. Fig. 8 illustrates a satisfactory furnace wherein it will be noticed there is a fire-brick lining to the fire-box and ash-pan, the latter forming a hearth in place of a fire-grate. Air is admitted through dampers, and combustion should take place under the fire-brick arch. It is the custom to re-model the blast appliances in the smoke-box of oil-burning engines, as unless this is done there may be a tendency for the products of combustion to pass through the upper rows of tubes in preference to the lower; there must be a good distribution of gases over the whole tube-plate. With correct adjustment of

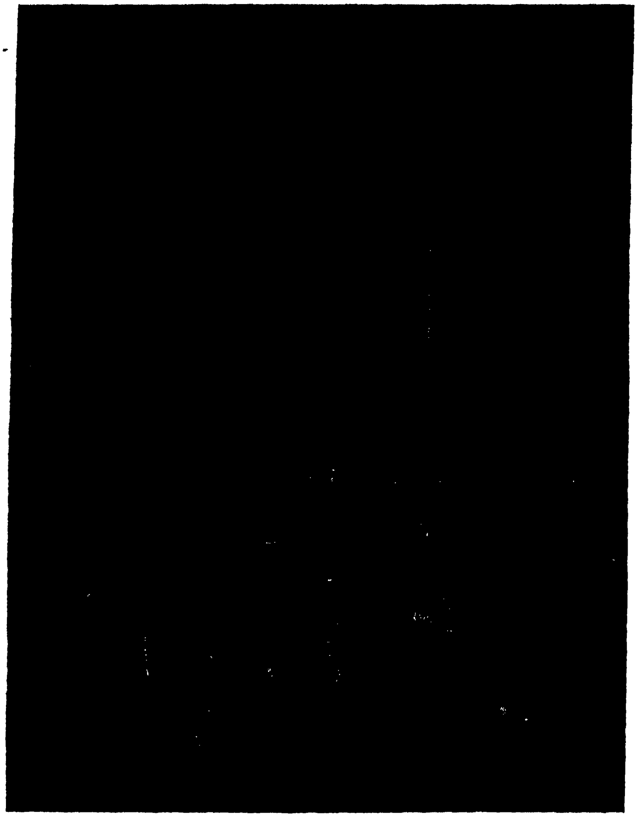


FIG. 6—END OF TENDER, SHOWING CONVEYER FOR MECHANICAL STOKER.

burner and dampers, perfect combustion should result, whilst steady steaming is assured.

Advantages of Oil Fuel.

Generally speaking, with oil costing twice as much as coal of good heating value, the results are about equal, but there may be other advantages where excessive transport charges, labour, etc., come into the question and so justify higher cost for the oil. The grade of coal available may also be so low that its efficiency as steam-raising fuel is seriously impaired.

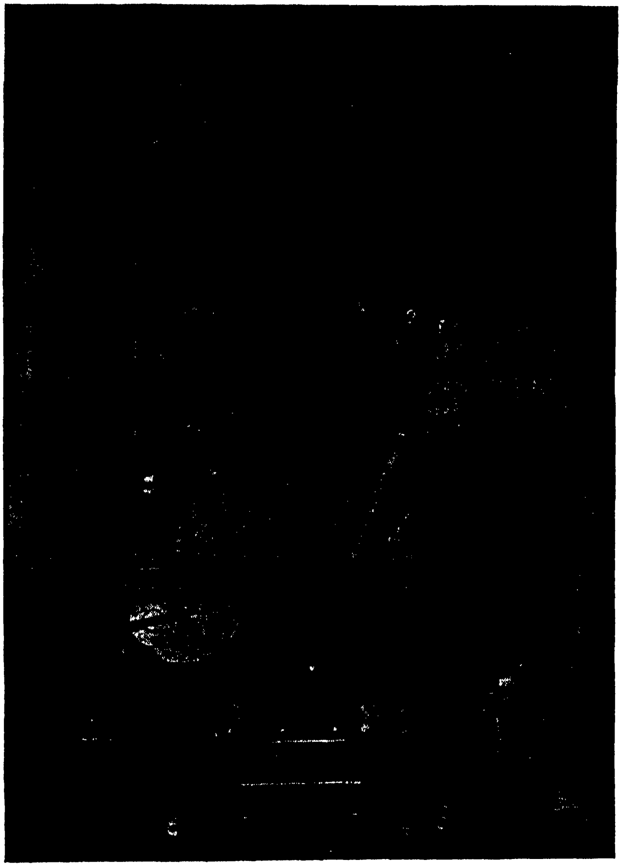


FIG. 7.—FOOTPLATE, SHOWING MECHANICAL STOKER.

In the diagram the burner, or atomizer, is shown inclined to direct the spray up to the under side of the brick arch; it is operated by dry steam taken from the top of the turret on the fire-box. Lighting up and steam raising is performed by injection of oil fuel by a hand-operated force-pump (shown), thence through a vaporizing coil temporarily placed on the hearth and heated up by burning waste, or wood, thrown in. As soon as steam is raised to a pressure of, say, 10 lbs. per sq. in., the main steam atomizer can be started, and normal conditions of oil-firing begin.

Pulverized Fuel.

Another development must be mentioned here: the use of pulverized fuel wherein low-grade coal, lignite, etc., can be successfully utilized on locomotives. The coal is passed through a ball mill, or pulverizing plant, and then fed to the furnace in the form of fine powder, blown in by a blower with air draft, in similar manner to oil fuel. When suitable material is available the results are claimed to be good. Fig. 9 shows a large 2–10–0 freight locomotive of the German State Railways, which is fired in this manner with a low-grade coal or lignite.

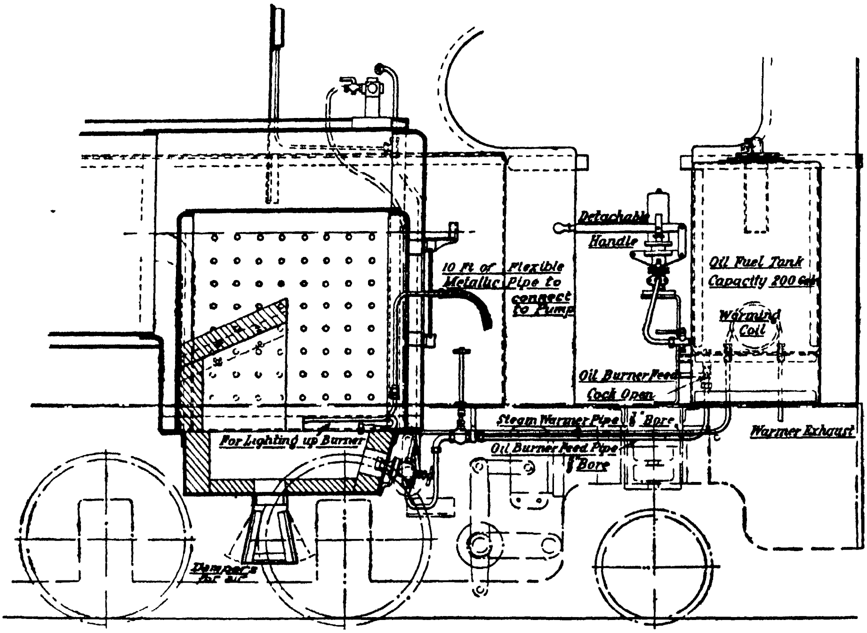

Detachable Handle
10 Ft of Flexible Metallic Pipe to connect to Pump
Oil Fuel Tank Capacity 200 Gal
Warming Coil
Oil Burner Feed Cock Open
Steam Warmer Pipe ½" Bore
Warmer Exhaust
Oil Burner Feed Pipe ⅜" Bore
For Lighting up Burner
Dampers for air

FIG. 8.—OIL-FIRED FURNACE.

A type of burner has been devised which is particularly suitable for locomotives. It is called a “ diffuser ” burner, owing to its particular construction. It consists essentially of a truncated hollow cone, the larger front end of which is closed by a plate with numerous nozzle-shaped holes, whereas the small rear end joins a mixing device for the coal dust and air mixture entering at this point. The supply is thus split into fine jets when passing through the diffuser-plate, and results in a number of short flames which unite into one ball-shaped blaze; no special cooling of the burner is required. (See Fig. 10.)

Smoke Eliminator.

Designed to ensure complete combustion in the fire-box and to obtain a higher rate of evaporation even with inferior grades of fuel, it is claimed that the eliminator will prevent the formation of smoke, as well as eliminate to a great extent the trouble of spark emission from the chimney.

While the engine is standing in a goods-yard or station, steam from the boiler, regulated by a valve, is injected into the fire-box through special diffusers, introducing pre-heated air conveyed through tubes from the smoke-box for mixing with the gases as they are liberated from the coal, in such manner as to ensure perfect combustion. The fitting of the apparatus (Fig. 11) entails no structural alterations to the boiler, or any holes being drilled in any pressure space. The apparatus is attached to the smoke-box, air being drawn in through nozzles arranged below the door and designed to operate while running forward or backward. The apparatus operates automatically when the locomotive is running at any speed over, say, 10 miles per hour.

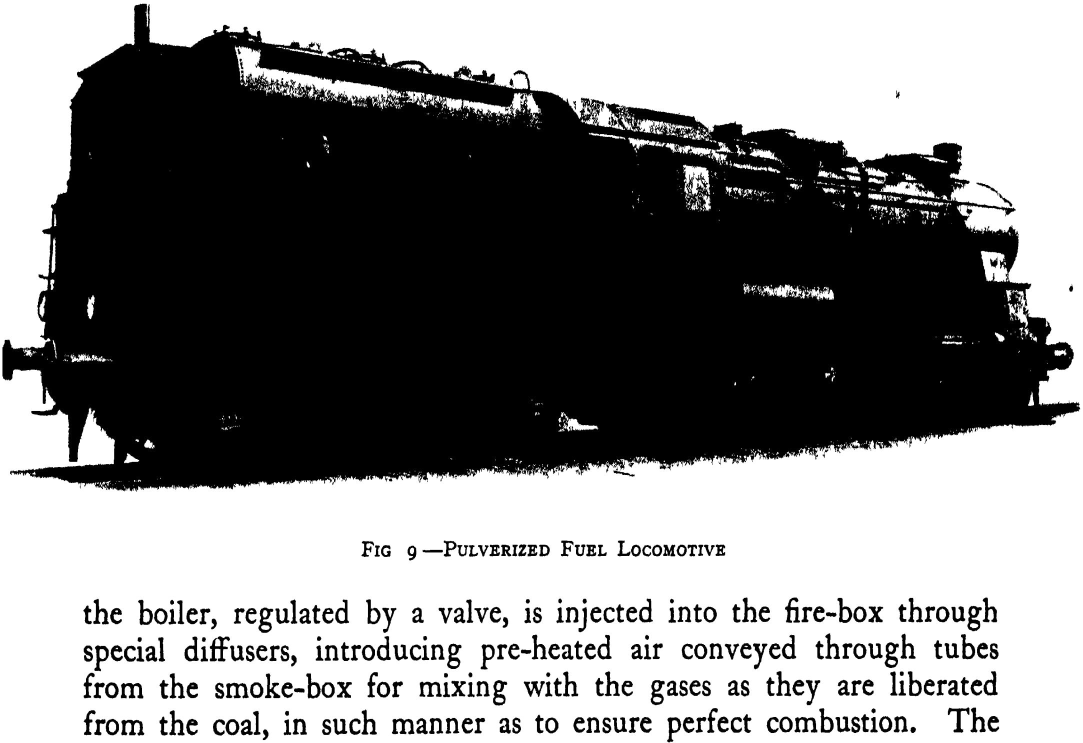


FIG 9—PULVERIZED FUEL LOCOMOTIVE

When raising steam in the locomotive the apparatus is set, and all that is necessary is to operate the handle of a steam-cock when the fire-box is being stoked up, then as soon as the hydro-carbons have been liberated from the fuel this cock is shut off. By getting better combustion in the fire-box, coupled with the absence of soot in the smoke-box tubes, the application of the smoke eliminator increases the thermal efficiency of the boiler, and secures economy in fuel.

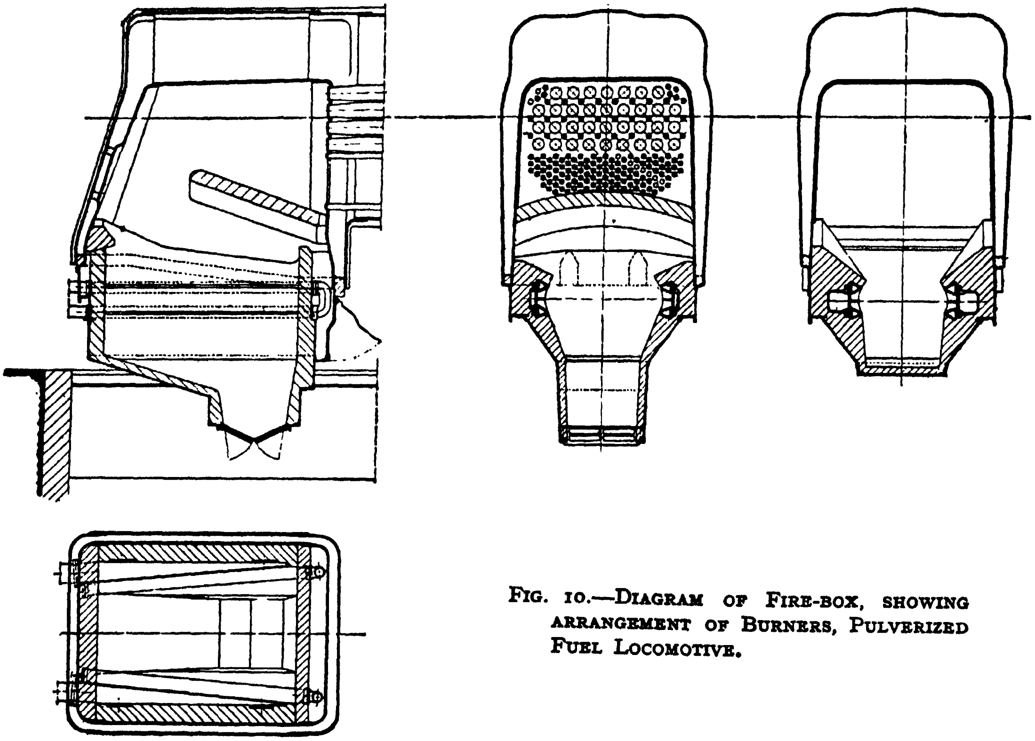


Fig. 10.—Diagram of Fire-box, showing arrangement of Burners, Pulverized Fuel Locomotive.

Other Devices.

By way of improving the combustion of fuel in locomotives and to secure proper distribution and diffusion of gases over the entire surface of the tube-plate of the boiler much ingenuity has been displayed in the arrangement of the blast-pipe and smoke-box, and in Fig. 12 one of the latest and most successful forms of improved front-end is illustrated, taken from a locomotive for the Paris-Orleans Railway.

In the first place, the orifice of the blast-pipe, whilst remaining circular, as in normal practice, is provided with a number of projections fixed around the inside periphery. These projections take the form of V-shaped pieces, the points of which are directed downwards into the blast-pipe.

Immediately over the blast-pipe and concentric with it is fixed a cylindrical "petticoat" pipe, and between this and the base of the chimney is arranged another extension, also cylindrical in form. Both the upper and lower extensions have their lower ends "flared" out or trumpet-shaped, and both are held in position by suitable stays at either side, bolted to the cap of the blast-pipe at their lower ends, and fastened to the chimney liner at top and bottom.

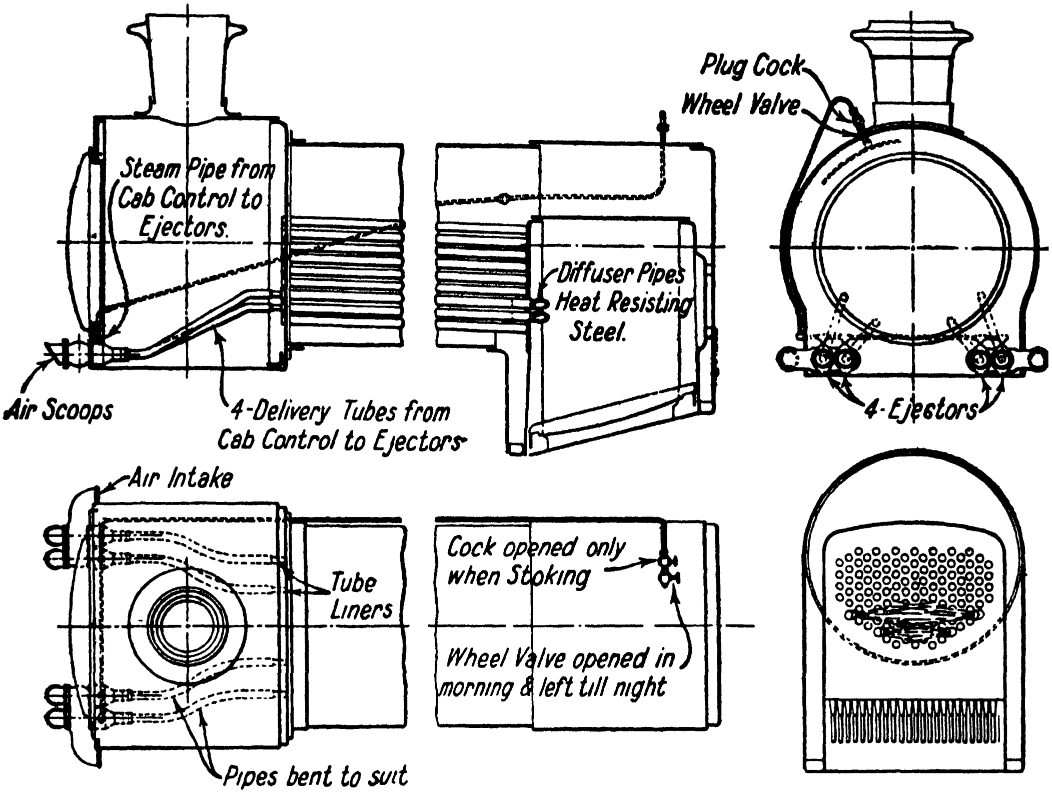

Steam Pipe from Cab Control to Ejectors.
Air Scoops
4-Delivery Tubes from Cab Control to Ejectors
Diffuser Pipes Heat Resisting Steel.
Plug Cock
Wheel Valve
4-Ejectors
Air Intake
Tube Liners
Pipes bent to suit
Cock opened only when Stoking
Wheel Valve opened in morning & left till night

FIG. 11.—GENERAL ARRANGEMENT OF PATENT SMOKE ELIMINATOR ON A LOCOMOTIVE.

The characteristic features of this arrangement are the construction of the blast-pipe cap or orifice already referred to, and also the form of the intermediate or lower extension piece or "petticoat" pipe. This particular section is sub-divided, being provided with divisions or cores intended to split up and expand the jets of combined gases and steam which enter the lower end.

The combined action of the projections in the main exhaust nozzle, and also of the sub-divisions in the lower petticoat extension, has the effect of splitting up the exhaust steam on its leaving the blast-pipe, and this action, combined with that set up by the sub-divided petticoat arrangement, causes the waste gases to be entrained by the jet of exhaust steam, and thus drawn out of the smoke-box more completely than is possible with the ordinary blast-pipe arrangement, which emits only a solid column of steam.

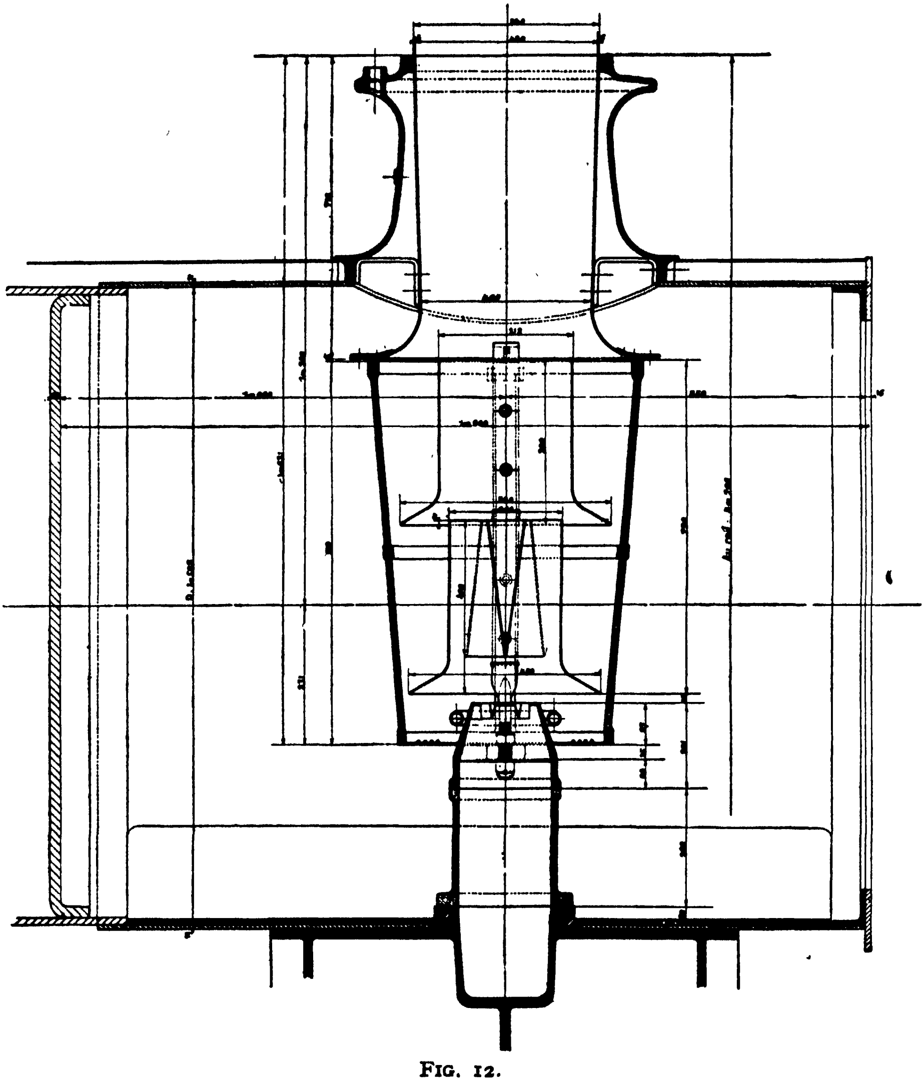


Fig. 12.

The action of the new blast-pipe combination is completed by discharging the broken column of steam and entrained gases through a perfectly cylindrical petticoat extension which is quite clear internally, the final discharge from which fills the chimney, and thus again restores the ejector action of the exhaust in the main chimney proper.

The higher efficiency of this new blast-pipe arrangement as compared with that of the usual type is due to the fact that its action is greatly improved by the splitting up of the exhaust. This sub-division allows of a larger orifice being used than would ordinarily be the case, which, in turn, reduces the back pressure on the pistons, and therefore less power is required for the blast.

Beyond this, the better exhaust action obtained improves the combustion process, and therefore the thermal efficiency of the boiler, which, together with the lower back pressure, gives the new blast-pipe obvious advantages over those generally employed which cannot well be overlooked.

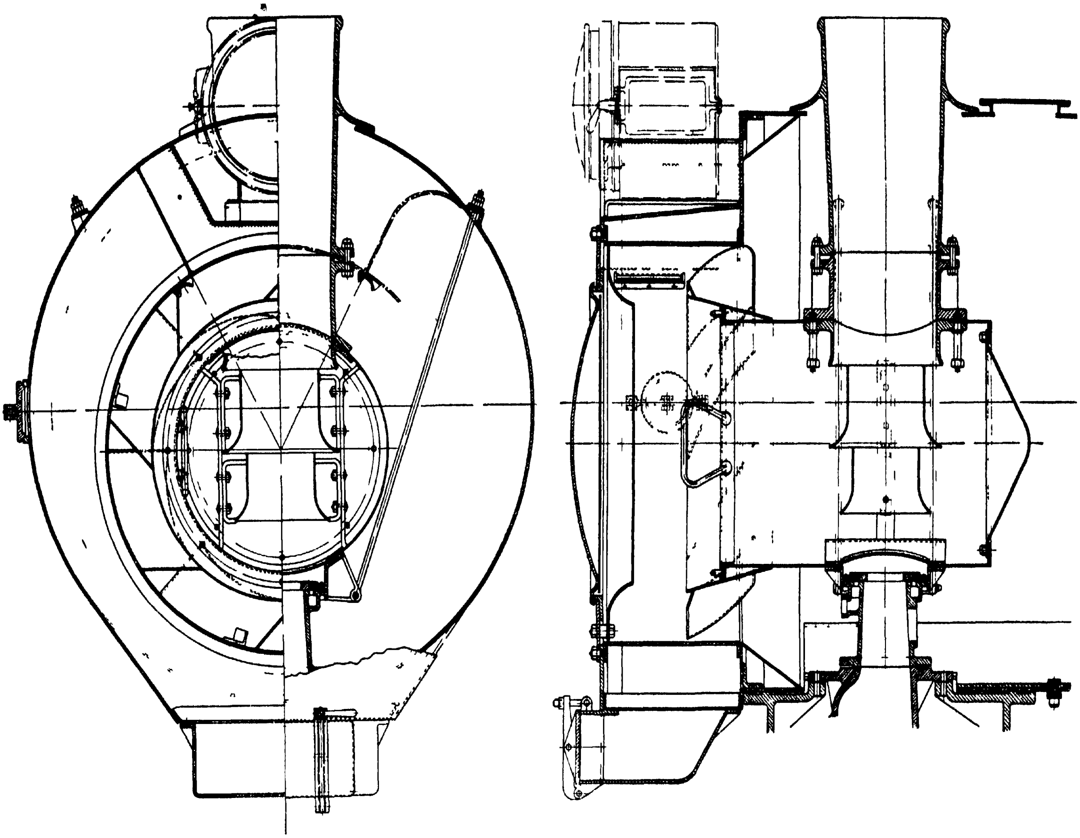


Fig 13—General Arrangement of the "Waikato" Spark Arrester, New Zealand Government Railways

The accompanying drawing, Fig. 13, shows a spark arrester fitted to the latest K class locomotives of the New Zealand Government Railways. It consists of a horizontal drum, or plate, located in the smoke-box, the back end of the drum being closed and openings provided in the top and bottom surfaces for connection to the base of the chimney and top of exhaust pipe. On the outer surface of the drum at the front end a number of helical blades are provided which fit into a chamber in the front of the smoke-box. At the top of this chamber and immediately in front of the helical blades, two openings with diverting vanes are provided, which openings communicate with an angular hopper located around the chamber, and which forms a receptacle for sparks and ash. A hinged door is fitted at the lower part of the hopper to allow of ashes being removed at sheds.

In operation the flue gases are drawn through the annular space between the external surface of the horizontal drum and the smoke-box proper. On passing through the helical blades the gases are given a rotating motion resulting in all sparks and solid particles being thrown outwards against the walls of the front chamber, where they are intercepted by the diverting vanes and passed into the ash hopper through the openings provided. The internal part of the smoke-box is automatically kept perfectly clean and free from ash, and in the event of the hopper becoming filled all cinders are thrown dead from the stack, the smoke-box still remaining clean.

The first " Waikato " spark arresters made were not provided with the hopper for catching ashes. In this design the ash was ejected from the chimney, but the sparks were so thoroughly ground up by being whirled against the walls of the smoke-box that they were extinguished before emission. It was, however, found that, especially with soft coal, the amount of cinder thrown out was a nuisance to the engine crew and the occupants of cars of passenger trains, and it was for these reasons that the cinder intercepting device and ash hopper were provided. Engines are now fitted with this modified arrangement which eliminates the emission of all cinder from the chimney and results in perfect cleanliness in this respect for the cars, besides making conditions more comfortable for the engine crew.

This feature of cinder elimination is of particular benefit where large engines are concerned, as with the usual form of netting spark arrester, engines such as the K class were found to be very dirty, particularly when burning soft coal.

CHAPTER XIII

Running Faults and Failures with the usual Remedies adopted—Defective Valves and Gear—Tests—Setting the Engine—Stephenson's Gear—Walschaerts Gear—Disconnecting an Engine—Broken Pistons—Connecting Rods—Coupling Rods—Springs—Axles—Loose Wheels—Broken Tyres—General.

Engine Failures and Remedies.

IT is very necessary that a driver, when taking charge of an engine, should personally see that everything is in good working order about it, and that it is supplied with fuel and water, as well as having a full equipment of tools. The different oil-cups should be correctly adjusted and filled with lubricant, and all visible parts of the motion carefully examined.

At the end of the day's work, all repairs, etc., that may be required, or any defects noticed during the run, should be entered in the shed-book appointed for the purpose, so that the engine receives proper attention before it goes out again.

With the most careful examination, however, there will always be liability to failure in service, owing to hidden flaws, weaknesses or breakdowns; for instance, priming may, as has already been mentioned, cause damage to various parts of the cylinders and strain the motion generally, whilst slipping, especially if sand be applied to the rails when the wheels are rapidly revolving and the regulator open, may cause the motion, coupling rods, etc., to be so severely strained, that breakage or failure is almost certain to ensue.

Before considering these mishaps and failures, or actually dealing with any specific defect, a few words may be given on the relative positions of the various parts of the motion with regard to each other. This will be convenient for reference, and enable many points to be more easily explained.

Taking a two-cylindered engine, it being the more common type in this country, the connecting rods are connected either to the cranks, of which two are formed upon the driving axle in the case of " inside " cylinder engines or upon the wheels in " outside " cylinder locomotives.

In either case these cranks are usually set so that one is a quarter of a turn in advance of the other; then, when one piston is at the end of its stroke and cylinder, with its crank upon the dead centre, and exerting no turning effect, the other one is at about the centre of its stroke, and its crank is in the position for exerting the maximum power, thus each crank in turn performs its share in the rotation of the driving wheels. It is by the position of the two cranks in regard to each other that it is possible to tell whether an engine is " right- " or " left-handed." When a crank-axle is revolved away from the observer, if that crank upon his right is a quarter of a turn in advance of that upon his left; the crank is said to be a " right-handed " one; if, however, that upon his left is in advance of that on his right by a quarter turn, it is termed " left-handed." (See page 60.)

It does not affect the working of an engine whether the cranks are right- or left-handed, but it does modify the relative positions of the parts of the motion when a driver sets his engine to " try her over." For convenience of reference, names and numbers are given to the various positions of the cranks during their revolutions; these names may vary somewhat, but those given herein are fairly common.

When an engine stands with one piston in its extreme front position, or end of its stroke, the crank that is coupled to it is said to be on its " front centre "; when the piston has moved to the opposite end of the cylinder, the crank is on its " back centre "; when the crank is exactly midway between the front and back centres and uppermost, it is said to be on its " top centre "; and when below, on its " bottom centre." These four positions divide the revolution into four equal parts, and are termed " centres." When the crank is half-way between front and bottom centres, it is on its " bottom front-quarter," midway between top and back, on its " bottom back-quarter," between back and top, upon its " top back-quarter," and when midway between top and front centres, on its " top front-quarter." The distance between each adjacent centre is thus sub-divided into two portions, and the path circle into eight equal parts. These terms are, of course, purely conventional, and are merely used for convenience of reference.

The positions are numbered as follows: For right-handed engines: when the R crank is upon the front centre and the L crank upon the top, the revolution is assumed to commence, and this is termed the " first " position; turning an eighth of a revolution the R crank reaches the "bottom front-quarter," the L being upon the "front top-quarter," the second position, and so on. Each eighth of a turn gives a " position." Fig. 1 shows a right-handed crank in each of the positions.

In a left-handed engine the same positions of the R-hand crank are taken, but the L-hand crank will be half a revolution in advance of the L-hand crank of the right-handed engines. Thus, in the " first " position the R crank is on the front and the left upon the " bottom "; " second " position R crank is on " bottom front-quarter," L crank is on " bottom back-quarter," and so on.

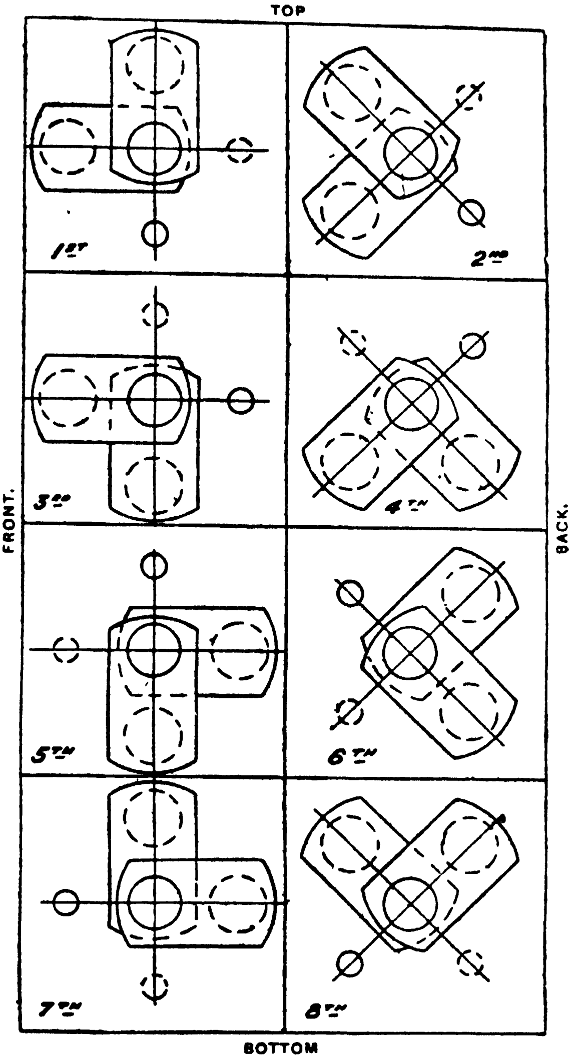


Fig. 1.—Diagram of Crank Positions.

The coupling or side rods of inside cylinder engines are usually placed exactly opposite the crank upon the same side of the engine. In Fig. 1 the small circles denote the positions of the coupling-rod pins, those in full lines being the left-hand side, exactly opposite the L inside crank, and those dotted on the right-hand pins being opposite the R inside crank.

The location of the slide-valves can be easily found on consideration, and as the connecting and piston-rods each side of the engine are always of the same length, it follows that the position of the crosshead will indicate the position of the piston connected to it. Thus, if the R crosshead is at the centre of the stroke, the R piston will also be at the centre of its stroke, etc. As the steam is admitted to the steam-chest it is by the aid of the slide-valves allowed to enter the port at one end of the cylinder, and force the piston to the opposite end, the slide-valve at the same time providing, by means of its cavity, for the escape of any steam to the blast-pipe which may be on the other side of the piston. As it moves along the valve opens the other port to steam, and connects the first-mentioned one to exhaust; thus the piston is alternately driven to and fro in the cylinder, imparting motion to the driving wheels.

NAWAB SALAR JUNG BAHADUR

By the foregoing, the ports open to steam can be easily ascertained. Thus, if the R crank is on the top centre, the R piston will be in about the centre of its stroke, and the L crank will be on the back centre—a dead position so far as any rotation of the crank-axle by it is concerned, and the R crank will therefore have to do all the moving of the axle. If, now, the reversing gear is put into the " fore " position, this crank must be pulled over towards the cylinder to revolve the wheels in the proper direction, and as the steam has to be admitted behind the piston, the back part must be open to steam. If it is desired to move backwards, the lever is shifted into " back " gear and steam admitted through the front port to move the piston towards the back of the cylinder. If the lever is put into " mid " gear, the slide-valve occupies a position midway between these two extremes and closes the ports. During these movements the L valve has not been shifted nearly so much as the R one has; in fact, only the difference by which the lead varies when in " full " and " mid " gears. In engines fitted with Walschaerts gear, and other motions where the lead is constant, the valve would not be moved at all.

When the wheels have turned half a revolution and the L crank is on the top centre, the L valve will have greatest travel, and the R valve will simply vary as the lead varies. These positions of the valves will be further referred to in the description of " blows " from failures.

Defects to cylinders most likely to occur in working, either from priming, wear or other causes, are breakages of the port bars or bridges between the steam and exhaust ports and passages; these are liable to crack or break, either by reason of faulty lubrication or broken slide-valves, which may catch in the ports in working. The cylinders themselves may break or crack in places when worn thin, generally along the top, where the smoke-box ashes, etc., accumulate and destroy the metal. Covers, pistons and rods, valves, spindles and stuffing-boxes will also get broken or blow, and these parts, being fairly accessible, are comparatively easily seen; but the failures inside the cylinders and steam-chest which are invisible without disconnecting the covers, etc., have to be detected by noticing the beats the steam makes when escaping up the blast-pipe.

When steam is admitted to the steam-chests of simple engines, and the engine is in working order, for each revolution of the driving wheels, four beats will be given; these should follow each other regularly, with a correct internal between. Where instead of four equal beats—say, three beats and a roar, or " blow " is given—it may be at once assumed that some internal part of the mechanism has become defective, and by observing the position of the cranks when the blow is given, the particular defect may be located.

If, when an engine is running, and during the whole time the regulator is open, a " blow " is given up the chimney in addition to the four distinct beats, it is indicating that the faces of one or both of the valves are bad, so that steam passes the port bar and so up the exhaust pipe. To ascertain which valve is at fault the engine should be set in the "first" position (R crank on front, L crank on top) and lever put in mid-gear. This will test the L valve, as its ports should be closed in this position; on opening the cylinder cocks, if any steam blows out of those on the left side it proves that the L valve is defective. To test the R valve, put engine in " third " position, R crank on top, and a blow-out of R cylinder cocks proves the R valve defective.

Such defects, unless very serious, may not be sufficient to make it necessary to give up a train, but they should be booked at the shed, so that the valve or valves may be examined and removed, if desired. Some engines have a few holes drilled in the back of the flange of the valves to the depth that the flanges are allowed to wear, so that when too thin they blow before breakage, and so give warning it is time to have them renewed.

Should a serious defect present itself which necessitates the uncoupling or disconnecting of one side of the engine, it should be located by the engineman, if possible, from observation of the beats and blows before stopping, he should then stop his engine in such a position that he can conveniently uncouple the necessary attachments and disconnect the broken or defective member without wasting valuable time in examining and testing valves and pistons. A broken piston, for instance, would give two beats and two blows for each revolution of the crank, and there should be no difficulty in ascertaining upon which side of the engine the damage exists.

If, while the engine is moving slowly, notched up in its running position with steam on, a blow is given as the R crank passes the front centre, and continues until it reaches the bottom centre, followed by an ordinary beat, then as the R crank reaches the back centre another blow, continuing until the crank passes the top, followed by an ordinary beat, it proves that the R piston is defective, allowing the steam to pass, because the R valve opens the R front port to steam as the crank is at the front, and there should be only a beat from the left-hand side; if a heavy blow is commenced, it is caused by the " lead " steam passing by the piston, and escaping directly up the chimney through the back port and the cavity of the valve. When the point of cut-off is reached the front valve is closed to steam and the blow stops; then, as the back port is opened the steam blows by the piston, through the front port to the blast-pipe, as before. If the blow is given when the L crank is in the positions indicated it of course follows that it is the L position that is at fault.

The magnitude of blows will, as a rule, be sufficient to indicate whether they are caused by a badly broken piston-head, or from leaky or defective piston-rings only. If they are very serious, and a broken piston is feared, it will be best to uncouple the defective side, as pieces of the broken head may become detached and catch in the ports, or get between the remaining portion of the piston attached to the piston-rod, and one or other of the end covers, and break them. Leaky rings, however, need not necessarily cause a failure, and if possible the run should be continued unless a convenient depot is reached for changing engines; the trouble, however, should be booked, and the rings put into proper working order before the engine again comes out.

If it is necessary to uncouple, the slide-valve should be closed first, when possible, as otherwise if the regulator leaks at all, steam may accumulate in the cylinder and move the piston when the connecting rod is uncoupled from the crosshead, and cause injury to the men working on it, or do damage to the engine, but the methods of doing this work will be left until the blows have been dealt with.

Supposing a blow is detected and cannot be traced when running, the engine should be put into a siding where no delay is caused to traffic, etc., and the valves and pistons tested by steam. There are two methods of setting the engine for doing this work, both having their advocates; the first is with the cranks on the centres, and the second with the cranks on the quarters. The former method tests one side of the engine at a time, and the latter one end, that is, front or back of the cylinders, etc.

The best positions for testing on the centres are the first position for trying the L-hand side, and the third position for trying the R-hand side, because in these the side that is not being examined has its crank upon the front centre, for, as it is usual to set all the rods in the motion a little short—to allow for expansion when heated and also for the engine settling upon its bearing springs, there is more likelihood of ample lead being provided at the front end than at the back, so that the port at the front end is not closed in any position of the lever.

For testing on the quarters the best positions are the second for testing the front end, and the sixth for testing the back end, as then the small ends are in a straight line across the engine, and lie exactly side by side, so that by observing them it is easier to set the cranks as near as possible in the right positions.

A defective piston can best be determined by a blow up the blast-pipe rather than by escape from the cylinder cocks, as the tendency for the steam passing by the piston is to go up the blast-pipe by way of the port at the opposite end of the cylinder in preference to passing through the small hole in the cylinder cock; when examining blows from leaky or defective valves, port bars or faces, there is often a saving in time by using the cocks, in order to locate the defect.

Method of Setting on Centres.

Set the engine in first position, R crank on front centre, L crank on top centre, and put the brakes hard on so that the engine cannot move, put lever into fore-gear and open the regulator a little and a blow will be given up the chimney; on pulling up the lever into mid-gear this stops, but if this commences again as back-gear is reached it indicates that the L piston is defective and allows steam to pass it, as before described. If, however, the blow is not given in both fore- and back-gear, open the cylinder cocks and observe them as well as the chimney and see which the steam blows out of as the lever is moved. If the blow up the chimney is given in fore- but not in back-gear, and steam blows out of L back cock in fore-gear, but not in back-gear, the left back port bar is defective, and allows steam to pass direct from the steam-chest to the exhaust port as long as the slide-valve leaves the back port open to steam, and the blows from the L back cock stopping as the valve closes, proves that the valve is not at fault. If, however, the blow is given from the L back cock in both fore- and mid-gear, but not in back-gear, the back lap of L valve is defective, and does not close the port to steam. If no blow is given up the chimney in fore- and mid-gear, but there is one in back-gear, and no blow from the cylinder cocks on left-hand side in mid-gear, the L front port bar is at fault. If there is a blow in mid-gear from L front cock it proves that the front lap of left valve is bad and allows steam to pass by it when the port should be closed. If a blow up the chimney is given in all positions of the gear it proceeds from some defect in the other side of the engine, and gets through the opening for lead upon that side, and herein lies the advantage of setting the engine with the crank of the side not being tested upon the front centre, for, then, if there is a difference in the lead at either end of the cylinder, it is more likely to be noticeable there, the port being always open; otherwise if the lead was less and diminished as mid-gear was reached, and if the engine had been set in the fifth position with R crank upon the back centre, it would be possible to have a blow in fore-gear and none in back-gear, then it would be feasible to attribute it to a defective front port bar, whereas the actual fault might be a leaky R piston, for the engine might have lead in fore-gear but not in back. Such an error would not be so likely to occur if the piston was placed at the front end, as then if the lead was greater an error in the setting of the valves would not be so noticeable, and would not materially interfere with the blows.

If a blow is given all round, or if a defect is known to exist by reason of blows, given when running, yet none is noticed in the above position, and if the cause has not been located, the engine should be set in the third position R crank on bottom centre, L crank on the front centre, the lever put into fore-gear, and a little steam applied; then, if the blow is given up the chimney and stops as mid-gear is reached, commencing again as back-gear is approached, the R piston is defective. If the blow if given up the chimney in fore-, but not in mid- or back-gear, and there is no blow from R front cock in mid-gear, the R front port bar is at fault. If, however, the blow is from the R front cock in mid-gear, the front lap of R valve is defective.

If, when the engine is set in the first position and no blow is given from the chimney in any position of the lever, but on setting it in the third position a blow is given up the chimney in back-gear only, and there is no blow from R back cock in mid-gear, it follows that the valve is doing its duty, and the defect lies in the R back port bar; if the blow is given from the R back cock in mid-gear, it proves that the back lap of R valve is defective, and not covering the ports when in its middle position.

Method of Setting on Quarters.

If, instead of testing the engine by setting it on the centres, as above described, the other method—that of setting it on the quarters, is chosen, the mode of procedure will be as follows:

Set the engine in second position, R crank on bottom front-quarter, L crank on top front-quarter; then in the sixth position, R crank on top back-quarter, L crank on bottom back-quarter, and watch the chimney-and the cock-blows as before.

When the engine is in fore-gear, and a blow is given up the chimney on both second and sixth positions, the R piston is at fault. If the blow is given in both positions with the lever in back-gear, the L piston is defective.

If the chimney-blow is given in fore-gear in the second but not in the sixth positions, it may proceed either from the R front port bar or front lap of R valve, and to determine exactly which of the two it is, set the engine in the sixth position and put the lever into back-gear, and observe which cocks are emitting steam; if from the R cock, it is the front lap of R valve, but if no steam issues from the cock it is the R front port bar that is defective.

When a blow up the chimney is given in forward-gear in the sixth but not in the second position, it is the back lap of R valve, or R back port bar, and these again have to be separated by testing in the second position with lever in back-gear, then a blow from the R back cock proves it to be the back lap of R valve, but no blow from this cock determines that the R back port bar is at fault.

If a blow up the chimney is given when the lever is in back-gear in the second but not in the sixth position, either the L front port bar or the front lap of L valve is defective, and to ascertain which of them it is, put the lever into fore-gear and the engine in the sixth position, and a blow from the L front cock indicates front lap of L valve defective, whilst no blow from this cock shows that it is the L front port bar that is causing the trouble.

If a blow up the chimney is given in the sixth but not in the second position, with lever in the back-gear, it is either the L back port bar or back lap of L valve, therefore put the engine in the second position and lever into fore-gear, and a blow from the L back cock indicates the back lap of the L valve, and no blow from this cock proves that the L back port bar is defective.

Having located the defect by the blows, or seen it if visible, and determined that it is necessary to uncouple the defective side of the engine and work on with the other, it will be best in all cases to disconnect the valve-gear and fix the slide-valve in its central position, and thus close the ports to steam to remove any risk of danger from the piston and connecting rod moving.

Valve Gear Details.

In the Stephenson, or shifting link motion, still a common form of valve-gearing for locomotives, as already explained (p. 72), two eccentrics for each cylinder are fixed side by side upon the driving axle, one for moving forwards and the other for moving backwards, each of these being connected by means of eccentric rods, from the straps upon the eccentric sheaves to the quadrant link, the fore-gear rod being attached to the top of the link and the back-gear rod to the bottom of it. The quadrant block, which is carried by the intermediate valve spindle, slides into the slot of the link, so that as the link is lowered down it is moved nearer to the top of the link, and the fore-gear eccentric operates the valve for the engine to move forward, then if the link is lifted up, the bottom or back-gear eccentric and the rod works the valve for moving the engine backwards. When the link occupies a mid-position, the effect of the eccentrics neutralize each other, and there is practically no movement of the valves.

Assuming that the motion is arranged as in A, Fig. 12 (p. 73), it will be found necessary to take down both the eccentric rods and put the defective side out of action altogether, as the slot in the intermediate valve spindle is not deep enough to allow the link to travel in it if the quadrant block is removed and the rods left up, with the valve in its central position, the best way to begin the uncoupling is first to put the valve in its central position; if the defective side has the crank upon the top or bottom centre, this can be done by putting the engine into mid-gear, or if the other side is upon top or bottom centre, measure the distance of its intermediate valve-spindle socket from the gland and then place the side to be uncoupled in the same position, when the eccentric rods are off, and lock the spindle and valve by clips.

If it is possible to move the engine, the most convenient position for getting down the motion when hung in the manner under notice is to place the cranks in the eighth position, as then they are as far out of the way as possible; also, if the eccentric strap-bolts are all fairly accessible it will be found in most cases best to take down the straps with the rods, rather than to take the rods down alone by uncoupling at the butt ends when the bolts are in very awkward places, and also by removing the straps all anxiety as to whether they will foul the frame-stay or fire-box front when running will be obviated.

It may be easier to take out the pins through the forked end of the rods and the quadrant-link first, as then the rod may be moved up and down to get the strap-bolts into better positions; if so, put the engine into fore-gear to get down the back-gear rod, and into back-gear to get down the fore-gear rod, as they will then each be further from the saddles and easier to get at. Knock out the taper pins which hold the link-pins, by first closing the split at the bottom carefully, then give it a smart blow fairly on the point to cause it to be knocked out. A little time spent in doing this properly is not wasted, for if too hurriedly done the pins may be " burred " over at the points and a large amount of work caused in getting them out, unless a handy pin-punch is carried by the driver.

If, on careful observation, it is possible to move with the link still up, as would be the case if the defect made it advisable to run with the back port open to steam, then as it is only necessary to take out the quadrant block, the eighth position of the crank, with engine in back-gear, will be the best one, the pins through the quadrant block being then out of the way of the saddles on the link. As it is in no position possible to get a blow on the inner ends to these pins to drive them out, owing to the proximity of the other valve spindle, it will be necessary to ease them out carefully by means of a flat chisel, or small "tommy bar" pressed against the inside end of them and the other valve spindle, tapping round the hole at the outer end to draw them out; in this case patience also is generally found better than force.

The same remarks apply if the link is hung with weigh-shaft below, except that the engine would be put into fore-gear to get out the quadrant block pin, as the swing links would make it impossible for them to pass in back-gear.

All the motion in this design is upon the driving axle side, or behind the motion-plate, so that the crossheads are unlikely to be in the way of getting out any part of the valve-gear, but in some cases they also have to be considered.

A third method of hanging the link is shown at B, Fig. 12 (p. 73), and if the defect is not in any part of the valve motion itself the quadrant block can be taken out, for the link has a long slot in which it can freely move without fouling the ends of it. It will be necessary to watch carefully when the swing links are out of the way of the pin which has to be drawn out of the quadrant block, and as the position of the weigh-shaft and length of swing links vary so much when hung in this way it is impossible to give any definite position for setting the engine to remove this pin. In the example drawn, however, as the links are attached to the intermediate valve spindle, which in this case also swings between the slide-bars and upon the cylinder side of the motion-plate, the crossheads must be watched, or it will be impossible to draw the pins out if these are in the way.

If it is found necessary to take down the rods, the same position of the cranks—the eighth—when both cranks are upon the top quarters will be found the most convenient to take out the eccentric strap bolts.

In a fourth arrangement, as illustrated at C, Fig. 12 (p. 73), the motion-plate is carried forward to the centre of the slide-bars, so that the crosshead has to be out of the way for drawing the pin through the quadrant block, the rest of the motion may, as in the last example, be left up, as a long slot is provided in the end of the intermediate valve spindle, which in this case works through a guide fixed to the motion-plate.

In both the last-mentioned cases it sometimes greatly facilitates the getting out of the quadrant block pin, to uncouple the swing links at the quadrant link end first and swing them clear until the quadrant block is removed, and then couple up as before. This is especially the case when the engine cannot be moved in order to get the link in such a position that the swing links do not cover the pin.

It is extremely improbable that all the nuts upon the bolts through the eccentric straps can be taken off by means of spanners, especially if the engine cannot be moved to place them in good positions, it may happen, therefore, that the hammer and chisel will have to be resorted to, to slacken them.

Failures with Walschaerts Gear.

Faults as above are less liable to occur than with gears worked by eccentrics. This is mainly due to the lower frictional resistance of the Walschaerts gear, and also the fact that the external position usually adopted is much more favourable to inspection and maintenance; for this reason, breakdowns—when they do take place—are easily dealt with " on the road." In the event of failure it is usually desirable, if possible, to take down both the eccentric and connecting rods. The crosshead and valve stem can then be securely blocked, exactly as in the case of an engine equipped with the Stephenson gear. The radius rod should be disconnected from the reversing arc shaft. If the valve is blocked in its middle position, the cylinder on its damaged side will be cut out. If the connecting rod, crosshead and piston on the damaged side are in a condition to run, the connecting rod may be left in place, provided that there are relief valves in the cylinder heads. The relief valves should be removed, so that the cylinder can be lubricated and excessive compression avoided. With the eccentric rod down, and the valve securely blocked in its middle position, the engine can then be run with its other side. It is, of course, necessary to remove the rod between the crosshead and the combination lever, fastening the latter in the forward position. The foot of the lever can readily be secured to one of the cylinder cocks. If the damage is confined to the return crank or eccentric rod, or to the lower end of the link, and the latter is still supported on its trunnions, the connecting rod may be left in place, and the valve operated by the combination lever. To accomplish this, take down the eccentric rod, disconnect the radius rod, from the reverse shaft, and secure the link block exactly at the centre of the link. The maximum port opening on the damaged side will now be equal to the lead, and the cut-off will be very short; but the steam will at least do some work, and the engine can be reversed and both cylinders will be lubricated.

Disconnecting an Engine.

It will usually be found that the most handy place for uncoupling the " big-end " is either upon the front centre or the bottom front-quarter, as then the nuts upon the long bolts are farther from the cheeks of the cranks than in any other position; if placed on the centre, it should be ascertained whether it is possible to get the bolts out, as the height of the boiler may make it impossible for them to pass when the cranks are in this position. In some engines when the crosshead is towards the back-end of the stroke, the small end-pin cannot be drawn out owing to the valve-spindle guide and the motion-plate; this should also be noted before commencing to take the parts to pieces. The whole of the holding-gear being now in a slack condition, a piece of rope which can be secured to the handrail or other convenient fitting, should be passed down from above and tied to the big-end of the rod to support it whilst the big-end strap is being removed. The big-end bolts may both be removed, and if the crosshead is pinched forwards it will draw the rod out of the fork of the big-end strap, and it can be either held by the rope or lowered into the loop of the motion-plate, as found most convenient. The " small-end " pin should next be taken out to allow the rod to be removed entirely; it can be lowered to the ground by means of the rope, and then picked up and secured to the footplate for removal with the engine.

The long cotter securing the brasses in the big-end being taken out allows the glut-plate and front-brass to fall out, and on turning the strap up so that the fork-ends point upwards, it and the other brass in it will fall off and leave the crankpin free. The strap should have the two brasses, glut-plate, long cotter and bolts replaced in their respective positions, and the whole secured to the rod.

It should be noted that in many engines it is impossible to get the brasses out of the big-end straps until the set-screws holding the long cotter have both been entirely removed, as they will not allow the former to pass; it is therefore best to see that this is done before the cotter is removed. Further, as the cheeks of the cranks will not permit the set-screws to come out in most positions, it will be found best to remove them as soon as they are clear while setting the engine for getting out the other bolts, etc.

The crosshead should next be moved until the piston is at the extreme end of the cylinder, and secured there by locking the gland upon the piston-rod, and also by means of clips, when these are carried upon the engine, secured by bolts to the slide-bar to prevent the crosshead moving.

The cylinder-cock gear upon the defective side should be uncoupled and the cocks opened, so that if by any chance the valve should allow steam to pass this may not accumulate behind the piston and render this liable to be forced to the other end of the cylinder and cause damage.

There are two differences of opinion as to which end of the cylinder the piston should be secured; but all things considered, it is usually best to fix it at the back-end, as then the glands can be easily got at to lock the piston-rod, and also if the steam does happen to move the piston it will be forced to the front end, and damage here is not nearly so serious as it would be to the back end owing to there being no attachments, slide-bars, etc., fixed to it, only a plain cover, and this, if broken, can be easily replaced.

In the case of engines having four slide-bars and a fixed pin connecting the slide-blocks, there will necessarily be a strapped small-end, and the mode of proceeding to uncouple will be the same as already described for the big-end, excepting that it is not as a rule essential to take the strap and brasses off the pin, but simply to release the rod by taking out the bolts and leave the remainder in place, putting back the bolts in their respective holes, and replacing the nuts after the rod has been taken out.

In the above it has been assumed that the engine can be put into convenient situations, but such is not always possible. Very often, indeed, it is immovable in a particular position, and that one in which it is not easy to get at the big-end bolts, as would be the case if the crank was upon the top back-quarter or any position near to it, then it would be almost impossible, with the tools usually carried upon a locomotive, to get any of the nuts off. When this occurs, uncouple the small-end and drop it into the loop of the motion-plate, where it will safely ride whilst the engine is pushed along to get the bolts more accessible.

It may by chance happen that the engine gets set in such a position that neither end can be uncoupled; if this happens the breakdown must be looked upon as a complete failure, and proceedings taken as in the case of a broken crank-axle.

The most common failures that would render uncoupling necessary are broken piston-heads or rods, often due to the presence of water in the cylinders, broken or bent connecting rods, broken straps, broken crossheads, etc.; it does not follow, however, that any of these occurring will make disconnecting absolutely essential. For instance, if the piston-rod broke through the cotter hole at the crosshead end, the piston being driven forward with sufficient effort to break the front cover and become firmly jammed there, as is very likely to be the case if the crosshead was of the single bar type, it would not foul anything. All that would be necessary to be done in this case would be to close the valve, if any long distance has to be travelled in steam, or let the whole remain if there is only a short space intervening; in this latter case there would be a great loss of steam with considerable noise as it escapes through the broken front-end.

If the crosshead is of the four-bar type or any other that has a loose centre that would drop when the piston-rod is removed, it would in most cases be necessary to take down the connecting rod, as it would be likely to foul the motion-plate if it were left in position.

It is generally best to uncouple for a broken piston-head, as the broken and detached pieces may work through the ports, and the slide-valve fouling them will cause a much more serious failure; pieces may also get between the part that remains on the rod and the ends of the cylinder, and do further damage. Generally speaking, the boss of the piston pulls out of the disc, which remains otherwise intact or breaks up into several small pieces; as it is impossible to ascertain this for certain by casual observation, it is best to uncouple at once.

Pistons.

Defective piston-heads or rings require a certain amount of discretion on the part of the driver on the road. It has been found by experience that the weakest part and the most liable to fracture is round the thickened boss, through which the tapered end of the rod passes. The first indication of a defective piston-head or ring is the irregular beat of the engine as the steam enters the cylinder and passes by the defective rings or through the broken piston-head to the exhaust cavity of the valve, which will be open to exhaust. The blow only ceases at the point of cut-off for one stroke and the admission of steam for the next. A piston-head loose on the rod, owing to the nut working slack and shearing off the taper pin, can be located by a very bad knock at each end of the stroke.

Broken Connecting Rod.

This—if at the small-end—will render disconnecting necessary, excepting in a few cases where the motion-plate is situated well back towards the crank, so that the rod will safely ride in the loop of it, when it can be left up; as the risk of catching in the plate and doing serious damage is great, this is not recommended.

When the big-end strap or the rod itself near to it gives way as the piston is moving towards the front end, the small end of the rod will then remain connected to the small-end pin, and will safely lodge in the motion-plate, a piece of wood wedged between the back of the crosshead and the motion-plate adds to the security in preventing the former from moving. The big-end and strap will have to be taken off the crankpin, as they would, if left in place, be liable to damage the front of the fire-box or underside of the boiler; the valve in this case should be shut.

Big-end Bolts.

These will sometimes give trouble by breaking under the head or at the end of the screwed part. This is caused by the wear in the tapered holes, which get out of truth owing to excessive " knock " taking place on the big-end brasses.

Big-end Set-screws.

If the thread of these set-screws are not a good fit in the big-end strap, they are liable to slack back, causing the big-end cotter to fly out of the strap, and the screws, coming into contact with the crank web, are broken off. These screws should, therefore, be daily examined with a set-screw spanner.

When working with one side of the engine only a driver should be careful to see that he does not stop with the working crank upon its dead centre, as then it will not be possible to start again with steam without resorting to pinch bars under the wheels to commence movement, which is, to say the least, a very troublesome proceeding.

One broken coupling rod will necessitate the taking down of both in all cases, because if one rod was left up and the driving wheels happened to slip, a severe strain would be thrown on it and the crankpins, or when the crankpin upon the second wheel of the one pair was upon either its front or back centre, there would be no turning effect transmitted, and the rod and crankpins would be liable to breakage.

It is not desirable in all cases to take down the coupling rods when the connecting rod upon one side has been disconnected, for by doing this the engine is partially unbalanced, and therefore will not run so easily as it would do if they were left up.

Breakage of Coupling Rods.

These will generally be found to occur at or near the centre of their length, whilst failures of the crankpins usually happen when an engine is starting a train.

If the engine has four wheels coupled and a rod or pin breaks, both rods will have to be removed, and the engine worked as a single driver, but if it has six or more wheels coupled together, there are always joints in the rods, either in the leading or trailing length, or at the driving journal, to allow of the necessary vertical flexibility and whichever length of the rod breaks it must be taken down as well as the corresponding length upon the other side, and the engine worked with as many wheels coupled as there are portions of rods left on.

If the rods are jointed in the leading length, and the leading crankpin, or the leading length of the rod breaks, it will be necessary to take down the leading length upon the other side of the engine, uncoupling at the joint, but if the trailing length, or driving, or trailing crankpin breaks, the whole of the rods upon each side must come down.

When, however, the joint is in the trailing length, it will be exactly the reverse, and a defect to the trailing end will necessitate uncoupling the trailing wheels only, whilst one to the leading end will disable the whole. When the bush on the driving crankpin forms the knuckle joint, it is usually forced into the rod end by hydraulic pressure, and it is impossible for drivers to remove it; in such case the whole of the rods will have to come down for any failure.

It is not always necessary to give up a train when the engine has to be uncoupled, for with a moderate load it can usually be worked on, at least to a station where a change of engines can be arranged.

Putting sand, or allowing it to run, upon only one rail as the engine is starting a train or slipping, is often the cause of bent or broken side rods, as it puts very unequal strains upon them.

Broken or Lost Springs.

Such mishaps usually make it necessary to give up a train, as it is unsafe to run at speed under these circumstances, but it depends upon the position of the defect as to whether the engine is unable to run at all or not; for instance, if the axle that has a lost spring is one which has four bearings upon it, and one of the inside springs was defective, as most engines carry less weight upon the inside spring it would not necessitate giving up the train, whereas failure to one of the outside springs would be more serious.

If a spring upon an engine with only two bearings upon each axle breaks or is lost, it will be necessary to stop running and get into a siding to prevent delay to traffic. By means of a jack placed under the buffer beam or frame, the engine can then be lifted until the distance between the top of the axle-box and the horn-block is similar to that on the other side of the engine, then—a " distance piece " can be put in to keep it so—and it will be safe then to move the engine slowly to some place where a new spring can be secured.

When it is found necessary to lift up one end of an engine in this way, the jack is first taken to the opposite end of the engine, and placed under a convenient part of the frame, the weight of the engine is taken and distance pieces put between the top of the boxes and the horn-blocks, after which the jack is put under the opposite end, the lifting more easily performed than if no blocks were placed at the other end to form a fulcrum. Lifting at one end, without taking this precaution, will be a much longer job, since the engine will settle down upon the springs at the other end and necessitate a lift of double the distance before the weight of the engine is taken up.

Breakage of an Axle.

In most cases this will cause a complete failure, though occasionally it may be possible to work home. Assuming that the leading axle of a six-wheeled engine has broken, it will be necessary to telegraph for the breakdown van and a trolly; on arrival, the latter will be placed under the leading end to keep the weight of the engine from the defective axle. Blocks should be placed between the bottom of the axle-boxes and the horn-stays, before lifting on to the trolly, so that the disabled wheels and axle may be raised with the framing of the engine, until they are clear of the rails; in this condition the engine may be safely drawn home to have its defects attended to.

The above remarks will also apply in the case of the trailing axle of a six-wheeled engine.

The method of procedure with a broken crank-axle on an engine of this type would be somewhat as follows: first take down the coupling rods, and then uncouple the driving springs on both sides by removing the centre pins, taking care to see whether the springs are hung by links at the ends; in some engines they only press upon wearing plates, and the removal of the centre pin will allow them to fall together, and then if the operators are not prepared for this they are liable to injury. In order to remove the centre pin proceed as before suggested, place distance pieces between the top of the axle-boxes at one end of the engine, and the lift at the other end on the fulcrum so made, until the weight is raised from the driving spring, when the pins at the centre can be knocked out; turning the pins half round in the holes will make the removal easier; unless this is done the shoulders which may have become worn on them will catch at the edges.

When lowered, the engine will rest upon the leading and trailing wheels alone, the weight of the driving axle only remaining on the driving wheels. When the engine is down on the rails, remove the distance pieces and take the jack to the driving wheels and lift them clear of the rails altogether, placing blocks between the bottom of the axle-boxes and the horn-stays for them to ride on. The lifting can be done either by raising the wheels and axle as a whole, by going beneath and placing the jack under the centre of the axle, or it can often be best done by putting the jack under the outside of the boss of the wheel, or below the crankpin on one side, and when that is blocked-up safely, go to the other side and treat it in a similar way; either of these methods can be followed according to the build of the engine, and accessibility of the various parts concerned.

In the case of an engine which has leading and trailing carrying wheels, with four-coupled wheels in the centre, the end-wheels would have to be treated as described, and also the driving wheels, but the intermediate wheels could be put out of action by being lifted in a similar way to the drivers, taking off the rods and lifting the wheels clear of the rails.

Loose Wheels on Axles.

The coupled wheels of engines are fitted with keys to prevent them from working round on the axle; these keys sometimes work out. The first indication of this trouble is the cracking and breaking away of the paint round the extreme end of the axle.

Crank Pins.

These sometimes break off at the collar in the radius, which necessitates taking off the other side rod to allow of the engine being worked home.

Broken Tyres.

These can be treated in a similar way to defective axles, but this depends to a certain extent upon the method adopted for fastening them to the wheels; when studs through the rim are used, they will often be broken by the tyre springing open when fractured, and are then unsafe, but if rings with lips projecting into recesses in the tyre and wheel rim are employed they are much safer and will hold the tyre to its place even if it is broken. In any case it is not advisable to work a train with fractured tyres on the engine.

Tyres should be frequently and carefully examined. On sounding a loose tyre with a hammer it will be noticed that it has a very dull sound. The paint round the tyre and the wheel will in all probability be cracked or broken away in places. In frosty weather the sounding of a tyre with a hammer cannot always be depended upon, and it should therefore be carefully scrutinized with the aid of a lamp.

A broken eccentric strap, should it be one on the back-gear straps and the engine is running forwards, will not always necessitate the taking down of the fore-gear strap on the same side—but the defective strap and rod only. It will be quite safe then to run in fore-gear; the beats will not, however, be true, the valve movements being very erratic owing to being coupled up at one end only. If it should be necessary to reverse the engine and run backwards it can still be done without uncoupling, but as the eccentric rod actuating the valve will be at the top of the link and out of action, movement will not be communicated to the valve at all on the majority of engines, and this will simply remain stationary. It will be necessary to see that the valve, which has only a fore-gear rod coupled to it, is in its central position, so that the ports upon that side may be shut. Care should be also used to avoid stopping with the crank upon the other side on either its front or back centre, for then the engine will be unable to start when required.

Failures to the fore-gear rod or strap may be dealt with in a similar way—that is, if the engine is working in back-gear with the fore-gear rod removed. Both valves will operate but with irregular beats, and if the engine is reversed into fore-gear, the valve upon the defective side must be placed centrally, and the engine worked on one side only, as above described.

It is inadvisable to run fast with an engine in the above condition, as the fork of the eccentric rod, as well as the quadrant link, is liable to be damaged; a low speed should therefore be maintained. If the defect is such as to make it advisable to take down both eccentric straps and close the valve, it will not be necessary to remove the connecting rod on that side, but the cylinder should have plenty of lubrication as it will be running dry whilst no steam is admitted to it.

Eccentric sheaves will sometimes work loose on the axle, resulting in an unmistakable irregular beat of the engine. A good method, when examining these, is to tap each sheave gently with a hammer whilst holding the sheave with the other hand; if loose, the sheave will vibrate and give a dull sound.

Eccentric sheaves when shifting and required to be refastened can be secured by means of the set-screws which are usually provided to assist the keys in holding them in position on the axle. When no set-screws are employed there are no means by which a shifted sheave can be temporarily refixed and the gear upon that side had better be taken down and the valve closed; the connecting rod can remain up as before.

Failure of the Quadrant Link.

This will necessitate taking down both the eccentric rods connected to it and closing the valve. If one of the suspension links supporting the quadrant link breaks, or as is more common, especially in those engines which have but one support to each link, the saddle-pin upon the quadrant link seizes and breaks off; it can be left if the engine does not have to travel fast; if it does and it is necessary to " notch-up " it will be best before starting the engine to lift the link upon the defective side into about its running position. This can be found by putting the lever into the prearranged position and measuring the distance between the top of the quadrant block and the quadrant link upon the unaffected side, and then putting the one to be secured into a similar position, placing a piece of wood of the requisite thickness between the block and link, so that the cut-off shall be correct in running. When starting the train, which should only be attempted when delay would be caused by giving it up, the lever must be put into full gear. Then, of course, as only one side is coupled to it, the engine will give two heavy beats and two light ones per revolution, but when the lever is moved into its running position the engine will beat " square."

If it is necessary to reverse and run backwards with an engine crippled in this manner, the link must be lifted up still higher and a longer distance piece inserted between the quadrant block and link, and kept in as long as it is required to run backwards.

A Broken Arm upon the Reversing Shaft, supporting either link will require similar treatment as above, but if the arm which is connected to the reversing rod breaks, and upon which both sides depend, then both quadrant links will have to be otherwise supported in their required positions. This can be done if the shaft is fitted with adjustable bearings at the ends by tightening up the caps of these, and so holding the shaft. If necessary one cap can be slacked back and a piece of tin or other convenient substance inserted and the cap screwed up so that the shaft may be gripped and held; a broken reversing rod requires a similar remedy.

Should the reversing shaft seize in its bearings, or any other defect happen to the controlling gear so that it becomes immovable, the engine can be reversed by uncoupling the suspension links at the ends connected to the arms of the reversing shaft, and raising or lowering the quadrant links into their required position, and securing these there by means of blocks of wood in the links, as before described.

A broken valve spindle, if outside the gland, will render necessary the uncoupling of the valve-gear either by taking down both eccentric rods or by removing the quadrant blocks as described earlier, the valve can then be secured in its central position by causing the gland to grip the broken spindle. If the fracture is inside the steam-chest and the spindle is carried through the front cover and fitted with a gland there, this may be utilized for the same purpose, and the valve secured. But on engines having no front spindles the valve cannot be held safely without taking off the cover of the steam-chest and wedging the valve in the required position. This procedure is especially necessary on those engines having the two valves working back to back in a common steam-chest between the cylinders, as the disconnected valve not being held in any way to its face would be likely to get between the working one and the steam-chest cover, and so cause serious trouble. Except in those cases where time is of little importance, it will be best to consider a valve spindle broken inside the steam-chest a complete failure, unless the engine has separate steam-chests where there is no fear of the perfect valve catching the defective one. In the other contingency, the steam acting upon the back of the loose valve may keep it to its face, thus closing all ports. While it does this it will be good policy not to close the regulator so that the steam-chest may be kept full of steam and the valve kept up, the engine being stopped by reversing the gear and applying the brakes.

The cast-iron strips which are let into the backs of balanced slide-valves and the special springs connected with them require periodical examination owing to the deterioriation of such springs in service. A bad blow will result from a displaced strip, and this will greatly affect the steaming and efficiency of the engine.

If the slide-valve has a badly broken lap and it is necessary to disconnect the valve-gear, after the rods are removed, put the defective valve in such a position that it covers the exhaust and one steam port, leaving the other open. The cylinder cocks must be used to test when the closed port is tight by opening them and admitting a little steam to the steam-chest. In this class of mishap it is necessary to uncouple the connecting rod upon the defective side and take it down, pushing the piston to the end of the cylinder and fixing it there. Care should be taken to fix the piston at the opposite end of the cylinder to the open port as steam will have free access to the cylinder at that end, and if the piston were by any chance left there, it would probably be projected with great force to the other end of the cylinder and cause breakage.

Broken Valve.

A broken valve cavity is to all intents and purposes an utter breakdown. Inasmuch as the valve cavity is always over the exhaust port, the breakage of the cavity allows the live steam to pass at once from the steam-chest into the exhaust chamber, and a constant blow results, whatever the position of the engine or reversing lever. If the loss of steam is insufficient to seriously reduce the boiler pressure, the train can generally be worked forward until assistance can be obtained. Should, however, the breakage be a bad one, both valves should be disconnected by taking out the quadrant blocks, and then firmly secured to the spindles. There is then no possibility of the ports or sound valve getting damaged by contact with a portion of the broken one.

Broken Piston and Piston-rod.

The breakage of a piston-head may be due to various causes, priming being a common one. The fracture usually occurs round the boss through which the taper part of the piston-rod passes. The hole is recessed slightly at the larger end to permit of the boss being tightened on to a shoulder turned on the piston-rod. If a good fit is not made here when erecting, trouble is almost certain after the engine has been in service for a time, as the piston-head nut will get slack, then shear off the taper pin and allow the cylinder cover to be knocked out. Breakage of the cylinders, bending of the connecting rod, or damage to the big-end strap may also result.

Another common failure is the breaking of the piston-rod through the cotter hold across a fracture or hidden flaw which cannot be detected by casual inspection. It is a good plan to examine thoroughly all piston and valve spindle cotters by tapping with a hand hammer after the day's work.

In dealing with a locomotive with a defective piston, assuming it is an engine with inside cylinders, the best procedure is to place the big-end on the front " bottom-quarter " and tie up the connecting rod to the hand-rail by means of a piece of rope. Then knock out the big-end bolts and pinch the crosshead forward, which will release the big-end strap from the connecting rod. The " small-end " pin can next be removed and the connecting rod lowered to the ground by slackening the rope which suspends it from the hand-rail.

All broken or detached pieces of the defective piston-head should be carefully removed from the cylinder, as these may work into the steam ports and foul the slide-valves, thus causing more damage.

In locomotives with Stephenson link motion it will be necessary to take both eccentric rods down if there is not sufficient clearance in the " forked-end " of the intermediate valve spindle for the quadrant block to be taken out.

The slide-valve can be closed on the defective side, the engine being pinched along to get the big-end of this side on to its " top " or " bottom " centre, and the reversing gear being moved to " out of gear "; the slide-valve then occupies a central position covering both back and front ports, and is secured by a specially designed clip. The piston can be held at the back end of the cylinder by fixing clips on the slide-bars against the crosshead, or by fastening pieces of wood alongside the slide-bar by rope or spun yarn, one end of the wood being against the cylinder end and the other against the crosshead.

With metallic packed glands another means of locking the slide-valve can be adopted. Assuming that the locomotive has Stephenson link motion with a " drag-link " on to the intermediate valve spindle working through the guide cast on or attached to the motion-plate, the set-bolt which secures the brass bush in position can be removed and a longer one substituted which can be screwed hard into the drag-link or intermediate valve spindle, thus securing the valve in its closed position.

With the most careful examination of the visible parts of a locomotive there is still the liability of failure from hidden flaws and weaknesses which necessitate uncoupling if they develop whilst working a train.

The young engineman will find uncoupling an inside cylinder locomotive on the open road not nearly so easy a matter as when standing over a pit; but if a mishap occurs on the main line, uncoupling has to be done as expeditiously as possible to avoid unnecessary delays.

CHAPTER XIV

Shop arrangements—Machine Tools—Grinding, etc.—Boiler Construction.

Locomotive Shops.

As an example of a modern and very completely equipped works, considered by experts to be equal to any similar installation on the North American Continent, the lay-out and arrangements are illustrated of new shops recently built and equipped for the Canadian National Railway, at Point St. Charles, Montreal. With the illustration a full list of the machines, etc., is given. (See Fig 1.)

Commencing at the south side of the building, the first bay, 55 ft. 10 in. wide, is appropriated to miscellaneous work, springs, brake gear, etc. The second bay is 85 ft., and forms the erecting shop with 31 pits; at the east end the boiler shop takes a length of 216 ft. A third bay, 70 ft. wide, is utilized for heavy machinery, tenders, etc.; the latter occupies a length of 264 ft. A fourth bay, 54 ft. 6 in. wide, covers light machinery and bogie truck repairs.

The shops are built on concrete piles, necessitated by the low level of the site and its proximity to the St. Lawrence. The outer walls are of concrete carried up to a level of 5 ft. above the floors; from there (window level) red bricks are used with concrete bands above the windows. The shops are well lighted, the side windows providing 39·5 per cent. of the side-wall surface, whilst the roof has some 74,000 sq. ft. of glass. Artificial lighting is furnished by electric lamps with "holophane" reflectors suspended from the roof trusses. All heavy machines and most of the smaller ones are equipped with either bracket or portable light fixtures. The boiler and tender shops are wired for electric welding, and the erecting pits are also provided with plugs for electric power, to operate tools, etc.

It will be noticed from the list that lifting power is liberally provided, overhead travelling and stationary jib-cranes being installed wherever necessary.

The 200-ton travelling and lifting-crane, shown in the view of the erecting shop, is somewhat novel in design, as it is provided with 10-ton auxiliary hook or hoisting gear, which operates on the main girder

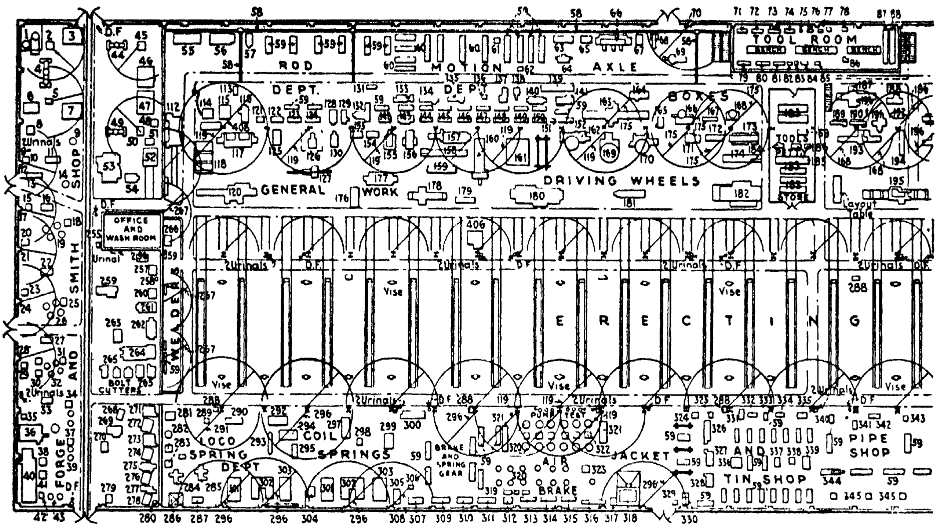


FIG 1.—ARRANGEMENT OF MACHINE TOOLS AND EQUIPMENT IN THE

FORGE AND SMITH'S SHOP

No. on drawing	*Machine*
1 . .	Exhaust fan (41,000 cu. ft. per min.)
2, 5 . .	Pillar cranes, 3 tons (23 ft. radius)
3, 7 . .	Double door billet furnaces
4 . .	Double frame steam hammer (3 tons)
6 . .	Hydraulic press (200 tons)
8, 15, 18, 25 .	Oil-furnaces (24 × 22 × 24 in.)
9, 14, 19, 26, 32, 39, 43 .	Buffalo down-draft forges
10 . .	Blower (900 cu. ft. per min.)
11 . .	Open frame steam hammer (7 tons)
12 . .	Column jib crane (10 cwt., 26 ft. radius)
13 . .	Hydraulic stock adjuster
16, 22, 27 .	Single frame steam hammers (1 ton and 8 cwt.)
17, 28 . .	Column jib crane (10 cwt., 23 ft. radius)
20, 23, 42, 258	Blowers (1350 cu. ft. per min.)
21, 24 . .	Column jib cranes (10 cwt., 20 ft. radius)
29 . .	Blower (1800 cu. ft. per min.)
30, 31, 34, 37, 41 . .	Oil-furnaces (14 × 14 × 24 in.)
33 . .	Single frame steam hammer (6 cwt.)
35 . .	Blower (675 cu. ft. per min.)
36, 259 .	Ring bending machines (6 × 6 × ¾ in.)
38 . .	Eye-bolt bender (1 in.)
40 . .	Oil-furnace (36 × 32 in. × 21 ft.)
44, 49 . .	Double frame steam hammers (30 cwt.)
45, 271, 273 .	Bolt forging machines (1½ in.)
46, 47 . .	Double door billet furnaces
48 . .	Blower (4500 cu. ft. per min.)
50 . .	Pillar crane (4 tons, 23 ft. radius)
51 . .	Electric carburizing furnace
52 . .	Case-hardening furnace
53 . .	Heavy forging machine (4 in.)
54 . .	Oil-furnace
255 . .	Floor grinder (24 × 3½ in.)
256, 261, 264	Bulldozers
257, 260, 262, 263, 268, 272	Oil-furnaces (various sizes)
265 . .	Bolt threading machine
269 . .	Forging machine (3 in.)
270 . .	Bar shears (1 in.)
274, 276, 278	Oil-furnaces (48 × 25 × 13 in.)
275, 277 .	Bolt forging machines (1 in.)
280 . .	Blower (675 cu. ft. per min.)

WELDERS

No. on drawing	*Machine*
59 . .	Benches
112 . .	Annealing furnace
118 . .	Oxygraph shape-cutting machine
266 . .	Electric welding generator
267 . .	Column jib crane (2 ton, 16 ft. radius)

CONNECTING AND SIDE RODS

No. on drawing	*Machine*
55, 56 . .	Double spindle rod borers
57 . .	Drill press (44 in.)
58 . .	Wall bracket cranes (2 ton, 25 ft. radius)
59 . .	Benches
113 . .	Hydraulic bushing press (120 tons)
114, 115 .	Vertical turret lathe (24 and 36 in.)
116 . .	Slotting machine (12 in.)
408 . .	Column jib crane (10 cwt., 24 ft. radius)
121 . .	Floor grinder (3½ × 24 in.)
122 . .	Bolt lathe (17 in. × 2 ft.)
123, 124 .	Lathes (21 in. × 15 ft., and 21 in. × 3 ft. 8 in.)
128, 129 .	Crank shapers (12 and 15 in.)
132 . .	No. 2 Churchill Internal grinder

GENERAL MACHINE SHOP

No. on drawing	*Machine*
117 . .	Rod boring machine (36 in. × 12 ft.)
119 . .	Column jib crane (2 ton, 24 ft. radius)
120 . .	Slab milling machine (36 in. × 16 ft.)
125 . .	Vertical milling machine (30 in.)
126 . .	Cincinatti plain milling machine (50 × 14 × 21 in.)
127 . .	Horizontal boring machine (36 × 84 in.)
153 . .	Plain milling machine (9 × 20 in.)
154 . .	Universal milling machine (12 × 15 × 42 in.)
155 . .	Slotting machine (16 in.)
156 . .	Vertical mill machine (24 in.)
157 . .	Faceplate lathe (7 × 16 ft.)
158, 159 .	Engine lathe (20 in. × 20 ft. and 40 in. × 7 ft.)
176 . .	Cold sawing machine (32 in.)
177 . .	Traverse head shaper (26 in. × 14 ft.)
178 . .	Planer (42 × 42 in. × 10 ft.)
179 . .	Heavy crank shaper (32 in.)

MOTION SHOP

No. on drawing	*Machine*
59. 60, 139 .	Motion parts, racks and benches
61 . .	Hydraulic bush press (120 ton)
62 . .	Screw press
63 . .	Young and Baker gear table
64 . .	Motion test table
131 . .	Buffing and polishing machine
133, 134, 135	Lathes (24 × 66, 21 × 54, 28 × 54 in.)
136 . .	Twin spindle drill (½ in.)
137 . .	Plain radial drill (3 ft.)
138 . .	Drill press
140 . .	Churchill link grinder
141 . .	Horizontal boring mill
142 . .	Landis grinder (10 × 24 in.)
143, 144 .	Universal grinders
145, 146, 147, 148, 149 .	Lathes (20 in. × 3 ft. and up)
150 . .	Lathe (60 in. × 5 ft. 6 in.)
151 . .	Pin grinder (12 in. × 4 ft.)
152 . .	Gap lathe (60 in × 5 ft. 6 in.)

DRIVING WHEEL DEPARTMENT

No. on drawing	*Machine*
119 . .	Column jib crane (2 ton, 24 ft. radius)
160 . .	Wheel press (500 ton)
161 . .	Electric tyre furnace
162, 169, 170	Boring mills (8 ft. and 8 ft. 4 in.)
171 . .	Gap lathe (60 × 16 in. × 5 ft.)
172, 173, 174	Engine lathes (30 in. × 8 ft., and 36 in. × 10 ft.)
175 . .	Column jib crane (10 cwt., 20 ft. radius)
180 . .	Journal turning and grinding machine
181 . .	Pin turning and quartering machine (90 in.)
182 . .	Heavy wheel lathe (90 in.)
406 . .	Wheel balancing machine

AXLE BOX DEPARTMENT

No. on drawing	*Machine*
58 . .	Wall bracket crane (1 ton, 25 ft. radius)
66 . .	Traverse head shaper (18 in. × 10 ft.)
67 . .	Sensitive drill
68 . .	Drill press (36 in.)
69 . .	Horizontal box press (100 ton)
70 . .	Column jib crane (10 cwt., 24 ft. radius)
163 . .	Planing machine (48 × 48 in. × 17 ft.)
164 . .	Heavy drawcut shaper (36 in.)
165 . .	Plain radial drill (3 ft.)
166 . .	Boring mill (48 in.)
167 . .	Engine lathe (25 in. × 3 ft.)
168 . .	Driving axle-box boring machine
175 . .	Column jib crane (10 cwt., 20 ft. radius)

SPRING DEPARTMENT

No. on drawing	*Machine*
281 . .	Blower (1350 cu. ft. per min.)
282 . .	Buffalo down-draft forge
283 . .	Electric furnace (24 × 22 × 24 in.)
284, 285 .	Spring banding machines (60 and 80 ton)
287 . .	Electric buckle furnace
289 . .	Spring testing machine (35 ton)
290 . .	Spring stripping machine (100 ton)
291 . .	Column jib crane (10 cwt, 20 ft. radius)
292, 294 .	Electric spring plate furnaces
293, 295 .	Spring cambering machines (⅜ × 7 × 72 and 84 in.)
296 . .	Column jib crane (10 cwt., 24 ft. radius)
297 . .	Hot punch and nibbling machine
298 . .	Oil-furnace
299 . .	Spring plate tapering rolls
300 . .	Spring plate rack
301, 303 .	Electric drawing and tempering furnaces
302 . .	Oil-treating and cleaning baths
304 . .	Elliptic spring eye-forming machine (½ × 5½ in.)

BRAKE AND SPRING GEAR

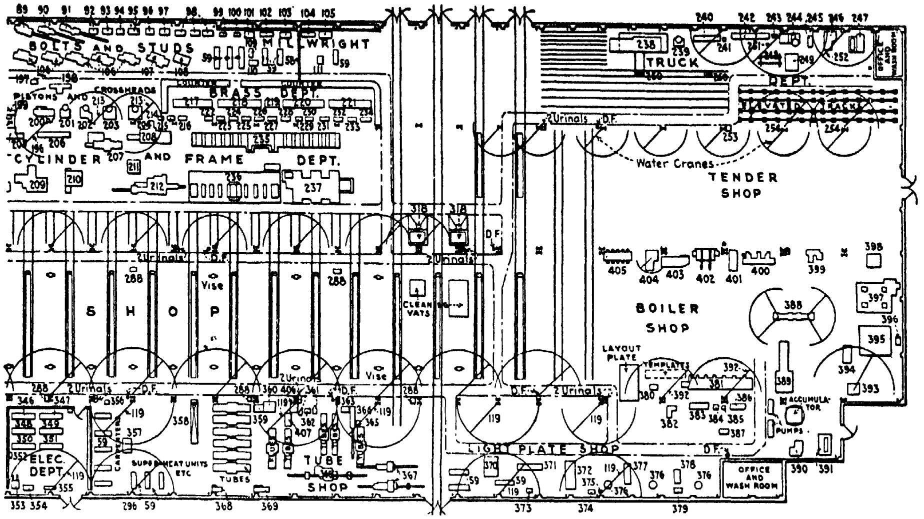
No. on drawing	*Machine*
59 . .	Benches
288 . .	Floor grinder (24 × 3½ in.)
296 . .	Column jib crane (10 cwt., 24 ft. radius)
305 . .	Drill press (42 in.)
306 . .	Hydraulic press (120 ton)
307 . .	Drill, 4 spindles (3 in.)
308 . .	Column jib crane (10 cwt., 24 ft. radius)
309, 310, 311	Engine lathes (26 in. × 8 ft. and 10 in. × 4 ft.)

AIR COMPRESSOR, ETC., REPAIRS

No. on drawing	*Machine*
59 . .	Benches
119 . .	Column jib crane (1 ton, 24 ft. radius)
312 . .	Drill press (40 in.)
313, 314, 315	Engine lathes (18 in. × 4 ft. and 21 in. × 3 ft.)
316 . .	Turbo-generator repair bench and test
317, 318 .	Cleaning vats
319 . .	Distributing brake, signal and feed valve test
320, 321 .	Pump repair tables and rack
322 . .	Vice stands
323 . .	Hydraulic press (33 ton)

JACKET AND TINSMITH DEPARTMENT

No. on drawing	*Machine*
59 . .	Benches
288 . .	Floor grinder (24 × 3½ in)
296 . .	Column jib crane (10 cwt., 24 ft. radius)
324 . .	Drop hammer (3 cwt.)



POINT ST. CHARLES LOCOMOTIVE SHOPS. CANADIAN NATIONAL RAILWAYS.

No. on drawing	*Machine*
325	Punch press (No. 18 gauge)
326	Plate rolls (¼ × 6 in. × 9 ft.)
327	Power squaring shears (No. 18 gauge × 8 ft.)
328	Hand brake (No. 10 gauge × 8 ft.)
329	Punch
330	Spot welder
331	Punch press (No. 14 gauge)
332	Circle cutter (30 in.)
333, 334	Sensitive drills
335	Lathe (10 in. × 3 ft.)
336	Squaring shears (No 18 gauge × 3 ft.)
337	Tin rolls (No. 18 gauge, 2 × 3 ft.)
338	Edging and circle cutter (No. 24 gauge)
339	Shears (No. 24 gauge, 30 in.)

TOOL ROOM

71, 72, 73	Tool lathes (20 × 72 and 16 × 36 in.)
74	Horizontal milling machine (9 × 15 × 33 in.)
75	Sensitive drill (½ in.)
76, 77	Tool grinders
78	Electric tempering furnaces
79, 80, 81, 82	Lathes (16 × 36 and 20 × 60 in.)
83	Universal tool grinder
84	High-speed steel cutting-off machine
85	Floor grinder (14 × 1½ × 1½ in.)
86	Power hack saw

TOOL AND PETTY STORE

59	Bench
183	Tool and material shelves
184	Sellers tool grinder
185	No. 2 universal cutter and tool grinder
186	Wheel grinder (14 × 1½ × 1½ in.)

FRAME AND CYLINDER DEPARTMENT

195	Planer (60 × 60 in. × 18 ft.)
207	Horizontal boring machine (48 in. × 10 ft.)
208, 212	Cylinder boring machines
209	Universal radial drill (6 ft.)
211	Cylinder fitting pit
216	Morton drawcut shaper (60 in.)
235	Frame planer (96 × 84 in. × 45 ft.)
236	Frame slotting machine (34 × 63 in. × 50 ft.)
237	Universal radial drill (6 ft., 3 heads)

PISTONS AND CROSSHEADS

168	Column jib crane (10 cwt., 20 ft. radius)
187	Planer (42 × 42 in. × 10 ft.)
188	Slotting machine (12 in.)
189, 190	Engine lathes (18 and 20 in. × 4 ft.)
191	Keyway milling machine
192	Drill press (20 in.)
193	Guide bar grinder
194	Crosshead press
196	Column jib crane (10 cwt., 18 ft. radius)
197	Grinder (24 × 3½ in.)
198	Vertical milling machine (14 × 22 in.)
199, 200	Engine lathes (32 in. × 5 ft., and 34 in. × 6 ft.)
201, 202, 203	Bullard vertical turret lathes (36, 42, and 54 in.)
205	Rod grinder (24 in. × 10 ft.)
206	Engine lathe (32 in. × 16 ft.)
213	Cylinder bushing mill (54 in.)

BOLT AND STUD DEPARTMENT

No. on drawing	*Machine*
89, 90, 91, 92, 93, 94	Turret lathes (2 × 10 × 36 in. and up)
95	Nut facing machine (2 in.)
96	Bolt lathe (17 × 24 in.)
97	Bolt centring machine
98	Bolt lathe (14 in. × 6 ft.)
106, 107, 108	Turret lathes (3½ × 36 and 6 × 24 in.)

MILLWRIGHT DEPARTMENT

58	Wall bracket crane (1 ton, 25 ft. radius)
59	Benches
99	Power hack saw (12 in.)
100	Sensitive drill
101	Drill press (36 in.)
102, 103, 104, 105	Lathes (16 in. × 5 ft. and 18 in. × 4 ft.)
109	Hydraulic press (33 ton)
110	Lay-out table
111	Jack testing machine (100 ton)

BRASS FINISHING DEPARTMENT

214	Auto-valve grinding machine
215	Cockgrinder
216	Milling machine
217, 218, 220, 221	Double work benches
219	Buffing and polishing machine
222 to 231, 233, 234	Brass lathes (16 × 24 in. and up)

ELECTRICAL DEPARTMENT

119	Column jib crane (1 ton, 24 ft. radius)
335	Test panel
346	Shop maintenance bench
347	Engine repair bench
348	Headlight armature repair bench
349	Turbo generator rack
350	Headlight turbine repair bench
351	Coil spreading and general winding
352	Turbo test rack
353	Armature and coil baking oven
354	Coil winding lathe

CARPENTERS

59	Benches
119	Column jib crane (1 ton, 24 ft. radius)
346	Wet grindstone
357	Universal woodworking machine

SUPERHEATER UNITS, THROTTLES, ETC.

59	Benches
296	Column jib crane (10 cwt., 24 ft. radius)
358	Unit testing machine

TUBE AND FLUE DEPARTMENT

119	Column jib crane (1 ton, 24 ft. radius)
359, 362, 363	Electric tube furnaces
360	Rotary tube welding machine (6 in.)
361	Pneumatic tube welding hammer
364	Hot saw
365	Tube expander
366, 367	Tube scaling machines (6 in. and in 2)
368, 369	Safe end cutting-off machines
406	Vertical abrasive machine
407	Electric tube welding machine (5 in.)

ASH-PANS AND LIGHT PLATE WORK

No. on drawing	*Machine*
59	Benches
119	Column jib crane (1 ton, 24 ft. radius
370	Laying-out table
371	Punching and shearing machine (⅜ in.)
372	Plate rolls (⅜ × 12 in. × 8 ft.)
373	Floor grinder (24 × 3½ in.)
374	Blower (1000 cu. ft. per min.)
375	Exhaust fan (1½ in. static pressure; 4500 cu. ft. per min.)
376	Forge fires
377	Hydraulic plate clamp
378	Bradley helve hammer (10 cwt.)
379	Hydraulic press
382	Universal radial drill (5 ft.)
380	Hydraulic close corner punch (100 ton)

BOILER SHOP

381	Plate planing machine (1 in. × 32 ft.)
383	Staybolt threading machine (6 spindles)
383a	Sensitive drill
384	Tell-tale hole drill
386	Staybolt lathe (14 in. × 5 ft.)
387	Anglebar shears (3 × 3 in.)
388	Throat punch and shear (1 in. × 5 ft.)
389	Horizontal plate bending rolls (1 in. × 20 in. × 14 ft.)
390	Gap riveting machine (37 ton)
391	Gap riveting machine (125 ton, 12 ft.)
392	Column jib crane (1 ton, 20 ft. radius)
393	Pillar crane (4 ton, 25 ft. radius)
394	Sectional flange press (37 ton)
395	Plate flanging furnace
396	Blower (2200 cu. ft. per min.)
397	Hydraulic flange press (575 ton)
398	Straightening block
399	Rotary bevel shears (1 in.)
400	Foundation ring and flue sheet drill (3 in.)
401	Radial drill (6 in.)
402	Tube sheet drill (2 spindles)
403	Straightening rolls (½ × 12 in. × 8 ft.)
404	Radial drill (4 ft.)
405	Rack for smoke-box fronts

TRUCK DEPARTMENT

238	Heavy car wheel lathe (52 in.)
239	Boring mill (60 in.)
240	Hydraulic wheel press (400 ton)
241	Column jib crane (1 ton, 20 ft. radius)
242	Journal turning lathe (52 in. × 10 ft.)
243	Bolt lathe (17 in. × 2 ft.)
244	Tyre boring mill (48 in.)
245	Shaping machine (24 in.)
246, 247	Radial drills (6 ft and 5 ft.)
248	Tyre setting trestles
249	Electric tyre heating furnace
250	Pneumatic wheel jacks
251, 254	Column jib cranes (1 ton, 26 ft. and 21 ft. radius)

PIPE SHOP

59	Benches
340	Power hack saw (18 in)
341, 342, 343	Pipe threading machines (2, 4, and 6 in.)
344	Hydraulic pipe bending machine
345	Forge fires

between the two main lifting-trolleys. This crane has the full run of the erecting shop, as also has the 40-ton crane on the same track—this also traverses the boiler shop. On the lower girders (shown in the photograph) are two 15-ton cranes which operate over the full length of erecting and boiler shops.

The pipe system for conveying different forms of power, water, oil, etc., has been specially studied, and a most complete installation made with welded joints, all valves above 2 in. in diameter are flanged; connections for compressed air, steam, etc., are provided wherever required. To enable the different lines to be easily traced they are coloured as follows: acetylene—*red*, oxygen—*light green*, live steam—*yellow*, exhaust steam—*brown*, vacuum—*drab*, air—*lead*, drinking-water (joints not welded)—*white*, hydraulic—*light blue*, wash-out—*dark blue*, non-potable water—*green*, oil—*black*, gas—*dark red*, gasoline—*orange*, electric—*aluminium*.

For flooring, wood blocks laid on a reinforced concrete foundation are used, except in the smithy where ashes are laid, and the spring and tender shops where concrete forms the surface.

Heating is provided for by 81-unit heaters, each operated by a 2-H.P. motor, and supplied with exhaust steam at 5 lbs. per sq. in. These heaters are hung in the roof trusses, and are automatically controlled to maintain a shop temperature of 65° F.

Lavatory accommodation, drinking-fountains, foremen's offices, etc., are all of the latest, whilst tracks for the movement of power trucks are outlined by white lines on the floors.

The number of men employed, including clerks and supervisors, is approximately 1175.

Machining Cylinders.

A machine designed especially for boring, drilling and milling locomotive cylinders is shown in Fig. 2, made by Messrs. Kendal & Gent, of Gorton, Manchester, for the Great Western Railway works at Swindon.

The bed of the tool is of box section, with the main slides formed on it and accurately planed and surfaced. A circular base supports the uprights, the latter being traversed along the bed by a large diameter screw. These uprights, of the central thrust type, have a swivelling movement of 90°, operated by a ratchet. The wings are of strong section, as they enclose the weights for balancing the saddle, which is mounted on machined and surfaced vertical slides. A variable self-acting reversible feed is provided for traversing this along the bed for milling purposes, with rapid adjustment for setting; it also has hand-feed for special work.

The compactly designed saddle moves on vertical slides on the uprights and is balanced by the weight previously mentioned; it has hand and variable self-acting reversible feeds for milling in a vertical plane, with quick power for setting purposes.

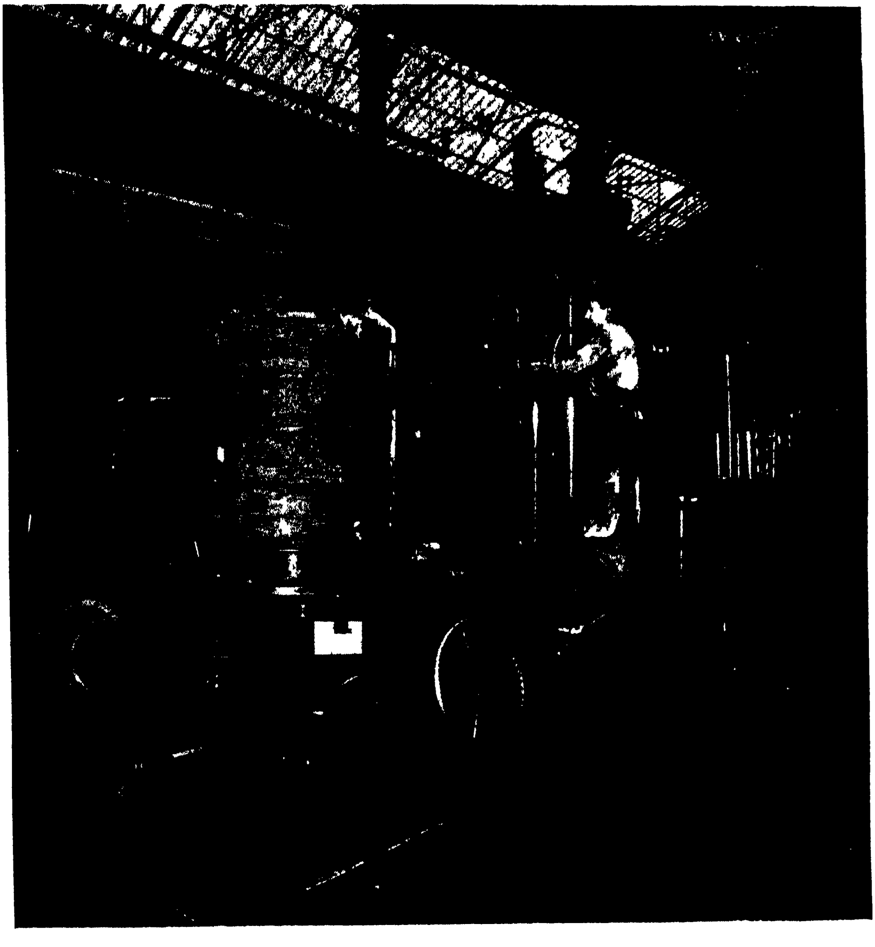


FIG 2—CYLINDER BORING AND DRILLING MACHINE

A high carbon steel spindle revolves in gun-metal bearings, the thrust in each direction being taken by ball-thrust washers. The front part of the spindle is carried in a steel sleeve, adjustable by hand as well as by a self-acting feed, providing six changes. These feeds are positive and reversible, the changes being made by sliding gears of high-grade steel, running in an oil-bath.